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A native village in the hill country of India.

INACCESSIBLE NEPAL, ON THE BORDERS OF INDIA.—[See page 357.]

Patents and Their Purpose

Notes of Historic Interest

By Jeremiah Lee MacAuliffe

THE history of industrial arts is the history of patents. The patent laws exist because of the cold fact that in no other practical way can public knowledge of new inventions be obtained. An invention, being at first possessed by the inventor alone, may remain his secret. If the nature of the invention permits, it may be made profitable to him by remaining his secret, and without advancing the public interests, or increasing the sum total of man's knowledge. The grant of patents, therefore, has this all-sufficient justification—it is a means by which the inventor can be induced to impart his secrets to the world at large.

INDUSTRIAL GRANTS AND PATENTS FOR INVENTION.

Originally, patents granting exclusive manufacturing privileges were not confined to inventors. They were granted to those introducing a new industry into a country, and especially is this true of England, though patents of the kind had previously been granted to some limited extent at least, on the continent of Europe. Earlier monopolies by Greek and Roman merchants, without authority from government, are referred to by Robinson in his very comprehensive and scholarly work on patents.

INVENTION.

By a comparison with the earlier grants, the character of letters patent of to-day is more clearly seen, as well as the gradual approach to the requirement of "invention" which now is universally a condition precedent to the grant of a valid patent.

Very early the importance of industrial development was realized. We are told by Schlosser that Alexander the Great made a determined effort to gather a knowledge of the inventions of all nations, and to disseminate this knowledge among his own people and those subjugated by him, *with a view to promote contentment and prosperity.* Other interesting examples abound in antiquity and in the middle ages.

INSTANCES OF DISCOURAGEMENT.

Exceptions to the general encouragement of inventors are recorded, noteworthy being the refusal by Queen Elizabeth (1589) to grant a patent for the knitting machine to its inventor, William Lee, M.A., of Cambridge (Knight's Mechanical Dictionary). More modern instances of a hostile attitude will be readily recalled in the doubts originally expressed as to the benefits, to labor and to society at large, to be obtained from the sewing machine. Another instance is that of the riotous actions of wood sawyers and carpenters, whose obliquity of vision led them to violent opposition to the introduction of the power sawmill and planer in the United States, and in Great Britain and Ireland, and made them feel contentment with even the lot of the "bottom sawyer," rather than to accept the promised improvement in conditions to be brought about by the new machines.

Industrial corporations flourished in Flanders, in France, Germany and in England, probably reaching their greatest power in Germany, where many of the free cities were formed into the Hanseatic League, in the thirteenth century. In these "free cities," which date from about the tenth century, it had been the custom to class the citizens in companies according to their occupations. The Hanseatic League enjoyed special privileges in return for services to the monarchs in whose realms it operated. The manufacturing corporations of Flanders at this period are also thought to have been at least temporarily dependent on the encouragement of the ruling sovereigns.

PATENTS FOR INVENTIONS ALONE SURVIVE.

For a long period the industrial development on the continent of Europe was far in advance of that found in England, and the latter exported little of manufactured goods except woolens. The industries of the continent, however, showed little indication of original investigation, and no marked progress in mechanics. England, awakening eventually to her backwardness, took steps looking to the establishment of new industries within her borders. She early invited foreigners, skilled in the different arts, to locate and establish manufactories in England; and finally she particularly recognized inventors as proper recipients of patents. Some of the grants recorded were mere letters of protection to foreigners settling in England. Others, even some of those to inventors, are to be noted as including only the exclusive right to manufacture, thus leaving open the right of importation and sale. It is worth mention that this medieval form of grant was substantially retained in the patent grants of Denmark as late as 1894, when a new law went into effect.

The issue of *Engineering* for June 22nd, 1894, calls attention to the fact that a vital feature of the modern patent, to wit, the general prohibition against the public other than the patentee, characterized grants of Elizabeth, and apparently the issue of the general prohibition was in response to a petition by an Italian inventor, one Acontius, in 1559, who urged this as a necessary part of the reward to the inventor. It has been suggested that Acontius was perhaps acquainted with the existence of similar monopolies on the continent. Another essential of the modern patent, the specification disclosing the invention, also characterized patents issued under Elizabeth, such a patent having been granted as early as 1561 for the manufacture of saltpeter. The first patent specification *accompanied by drawings* appears to be the British patent, No. 169, of 1673.

PURPOSE OF INSTRUCTING THE PEOPLE.

To revert to the early forms of grants, the letters of protection granted by Edward III, in 1331, to Johannes Kempe, of Flanders, to establish the manufacture of textiles in England, are perhaps notable in that they are granted avowedly for the purpose of *instructing the people* in a new industry. (Flanders at this time made higher grades of woolens than the English). The grantee obligated himself to teach all seeking a knowledge of his calling.

Almost in exact line with the purpose of this grant are the modern patent rights of all nations, as will later appear. The Kempe grant is not otherwise notable, however, since an industrial patent or grant, earlier by nearly two centuries, was given, according to Hallam, to the Weavers Company by Henry II.

The first systematic effort to establish manufactories in England by granting patents, was made in 1337 (*Law Quarterly Review* for April, 1896), when a general statute was passed, placing under the King's protection the cloth workers of other lands who came to dwell in England, "to the intent that said cloth workers shall have the greater will to come and dwell here, our Sovereign Lord the King will grant them franchises *as many and such as may suffice them.*"

If we are still interested in comparing forms of governmental encouragement of industry, we may take note of a significant incident having some relevancy to the subject, as related by Hume, who explains that an attempt to foster commerce and trade by encouragement from the Crown, was made in England by Athelstan (925-941): "He passed a remarkable law which was calculated for the encouragement of commerce, and which required some liberality of mind in that age to have devised; that a merchant who made three voyages beyond the sea on his own account should be known as a thane or gentleman."

What appears to have been the first patent for an alleged *new invention*, was granted in 1440 in England for new process of making salt. In a patent given to one George Bobham for an improved dredging machine, the object of the grant is made clear. It expressed the wish of Elizabeth that the favor thus accorded the patentee "will give courage to her subjects to study and seek for the knowledge of like new engines and devices." The granting of few patents in England, and the absence of material results, prior to the Elizabethan era, are accounted for by two causes, to wit: internecine wars, and the practical nullification of the patent statute during several successive reigns, when the skilled foreigners were invited *into the service of the Crown* instead of receiving franchises for the benefit of public manufactures.

INVENTORS ALONE ENTITLED TO PATENTS.

From 1600 the abuse of the privileges enjoyed by the holders of industrial monopolies resulted in the unmistakable public call for confining the grant of patents to inventors only, but promises of reform by Elizabeth quieted for a time the agitation against public monopolies. Finally, the dissatisfaction aroused by the gross abuses of the companies who controlled trade, culminated in 1623 under James I, and the noted statute against monopolies was passed. The English public, even when thus aroused over the wrongs suffered under the general monopolies, did not lose sight of the benefits to be derived by the public from encouraging inventors, and the very statute of repeal of monopolies specially recognized the propriety of granting exclusive rights to the inventors of new manufactures to enjoy their inventions *for a limited period of time.*

Much confusion exists among students of the patent laws regarding the statute of James I. This did not create any rights for inventors, nor grant them anything which they did not previously enjoy, but merely was in keeping with the decisions of the English courts, which, whenever occasion had arisen, had endorsed the validity of grants to inventors, while condemning industrial monopolies granted to others.

The patents granted under the statute of James did not as a rule *afford a disclosure of the invention*, and some British patents as late as 1750 contained merely the title. Moreover, under this statute of James, an invention was held to be patentable if it were not previously known in England; and it was of no moment that the invention was known and published in other countries.

The patent grant to-day the world over is like the Kempe grant of six centuries ago, in that one obligation is inexorably imposed and one condition exacted, the instruction of the public. The law requires a *bona fide* disclosure; and proof of a violation by the withholding of essential particulars invalidates the patent, as a contract void for the absence of a valuable consideration.

EARLIEST AMERICAN PATENTS.

THE first patent issued in this country was granted by the General Court of Massachusetts Bay Colony, in October, 1641, to one Samuel Winslow, for a new method of manufacturing salt. In recurring to this Winslow patent, and to the first patent ever issued for a new invention (1440), both for the manufacture of salt, we are strikingly reminded that patents for inventions are dictated by no mere sentiment, but by considerations of public welfare—even public necessity—which originally prompted in England, and later in this country, the granting of patents for new inventions in order to encourage and increase the production of this most important article. The term of the Winslow patent was ten years, and the grant was conditional upon Winslow's setting up works within one year. Several other patents were granted by the Bay Colony and other colonies in the same century. It appears that Massachusetts, Connecticut, and Pennsylvania were the principal members of the original colonies which granted patents.

The articles of confederation, adopted July 12th, 1776, contained no authority to grant patents; but the States issued them independently, as the three colonies above mentioned had done. Thus, in 1785, James Rumsey obtained special grants or patents from the States of Maryland, Virginia, Pennsylvania, and New York, for a "newly invented boat," which was practically tested on the "Potowmack" (Potomac) in September, 1784, in the presence of George Washington, who gave the inventor a letter highly commending the boat as "of vast importance in inland navigation." John Fitch, Rumsey's more successful rival and contestant, also received, at about the same time, similar patents, or exclusive privileges, from New York, Virginia, and Pennsylvania.

RECOGNITION OF INVENTORS RIGHTS—OBLIGATION OF GOVERNMENT.

The Constitution of the United States made provision for the encouragement of inventors, and in 1790 a patent statute was passed by the Congress. To the constitutional convention belongs the credit of, for the first time, embodying in the law of a nation the fundamental doctrine that an invention belongs by inherent right to the inventor, *and that to secure this right to him, with due regard to public interests, is an obligation of Government.* In 1836 the Patent Office was established, and provision made for the examination of inventions to determine their novelty, this being the first instance of such a provision in patent laws. The present laws are substantially those passed in 1870, which extended the term of the patent from fourteen to seventeen years, and prohibited extensions except by special act of Congress.

The proposition to give cash awards to inventors and throw the inventions at once open to the public gained some favor in Great Britain in 1869, but the proponents were silenced when reminded that the experiment had actually been tried more than a century before, and with ill success. A rather diverting item, showing some of the results of this experiment appeared in the SCIENTIFIC AMERICAN for September 18th, 1869. Inventions of real merit seemed, for some reason, to remain a secret under this cash plan.

Cash grants are not unknown in the United States. Thus Joshua Shaw, who in 1814 invented the percussion cap, was debarred from receiving a patent because he was an alien, but later the Government awarded him

$25,000 (SCIENTIFIC AMERICAN, August 7th, 1869). Also, in France, Daguerre and Niepce, in 1839, were granted annuities in recognition of their invention of photography, that could not adequately be protected by patent (Tissandier's History of Photography).

PROPOSITIONS TO REPEAL PATENT LAWS.

During the sessions of the sixty-third Congress, discussion of the patent laws became widespread, attention having been focussed on the subject by the introduction of the "Oldfield Bill," which proposed compulsory licenses. There were those who, not content with the suggestion of compulsory licenses, advocated the complete repeal of the patent laws. The reader may consult a report issued by the Cleveland, Ohio, Chamber of Commerce, 1913, for an admirable, critical study of the Oldfield bill, with a discussion of the patent system of the United States.

Bearing on the suggestions of repeal, the reader will be interested in an illuminating incident involving a similar proposal. In 1869 it was actually proposed in England to repeal the patent laws (see issues of SCIENTIFIC AMERICAN during September, 1869). The agitation to this end had its origin in an attempt by the millers to avoid payment of royalty to the inventor of an improvement which prevented the wasteful and unhealthful clouds of dust that theretofore were incidental to the use of millstones. The repeal was opposed by various bodies, including the Workingmen's Technical Education Committee, The Foremen Engineers' Association, The Workingmen's Club and Institute Union, The Public Museums and Free Libraries Association, and various workingmen's organizations. These not only opposed repeal, but demanded a more liberal patent law, which would give a patent as a matter of right, and for a reasonable fee. The patent laws of England at that time made patents very costly, and were productive of outrageous delays. An excerpt from an argument at this time is instructive:

"Mr. C. W. Siemens, F.R.S., a native of Prussia, left that country and came to reside in England, because practically no encouragement was accorded to inventors in Prussia. Mr. Siemens' regenerative furnaces and improvements in telegraphy had augmented our national wealth to the extent of several million pounds sterling, all of which was lost to Prussia through it having practically no patent laws." This policy has been reversed by the Germany of to-day. Siemens himself later delivered an address (SCIENTIFIC AMERICAN, October 16th, 1869) in which he said: "If we review the progress of the technical arts of our time we may trace important inventions almost without exception to the Patent Office. In cases where the inventor of a machine or process happened to belong to a nation without an efficient patent law, we find that he readily transferred the scene of his activity to the country offering him the greatest encouragement, there to swell the ranks of intelligent workers."

WHAT OF THE PATENT OFFICE?

Dickens, in his scathing exposure of the circumlocution office, with its staff from the ancient family of Barnacles, has shown that a very bad patent law can be made infinitely worse when administered with the purpose, How not to do it. In "Little Dorrit" we see the inventor, Daniel Doyce, of the firm of Doyce & Clennam, iron works.

"As an ingenious man, he had necessarily to encounter every discouragement that the ruling powers for a length of time had been able by any means to put in the way of this class of culprits; but that was only reasonable self-defense in the powers, since How to do it must obviously be regarded as the natural and mortal enemy of How not to do it. In this was to be found the basis of the wise system, by tooth and nail upheld by the circumlocution office, of warning every ingenious British subject to be ingenious at his peril; of harrassing him, obstructing him, inviting robbers (by making his remedy uncertain, difficult and expensive), to plunder him, and at the best, of confiscating his property after a short term of enjoyment, as though invention were on a parallel with felony."

If a bad law can thus be made worse, so also, a good law can be made better, by officials motived by How to do it. The United States Patent Office organization is dominated by the commissioner, the examination of applications being done by a corps of examiners separately in charge of approximately fifty different divisions. The corps includes first, second and third assistant examiners. Official actions of the examiners are checked up (when appealed) by the Board of Examiners in Chief, and the Commissioner.

When, in the war of 1812, the keeper of patents in Washington placed himself in front of the British guns trained upon his office, determined himself to be destroyed if the threatened destruction of his precious records was to be carried out, he established the standard by which Commissioners of Patents have generally chosen to be measured, so that we see men of national repute as patent lawyers exchange a very lucrative private law practice, for the honors of the commissionership.

The successive commissioners find at their service a body of examiners whose duties and jurisdiction are strictly defined by the statute and the official rules, but wherein, owing to the nature of the task, the personal equation may nevertheless become a factor beyond the power of law or rule to determine. Skilled in the sciences and in mechanics, learned in the law and practiced in its impartial application, the examiners judge and rule upon (subject to appeal) the questions, largely controversial, arising as to patentability and related matters, in the tens of thousands of cases annually presented—cases not infrequently calling for what, by any applied test, must be regarded as learning of a high order.

GUARDING PUBLIC INTERESTS IN THE PATENT OFFICE.

When Doyce became disheartened, after twelve years' effort to obtain a patent at the Circumlocution Office, and his junior member took up the unequal struggle, no vaticination could have foretold the voluntary action of American applicants in holding applications pending for twelve years and half of twelve more, by dilatory tactics, until it suited their purpose to have the patent issue. This wrongful practice has been effectively eliminated by a forceful commissioner, and we have, in his action, but one instance only of many, wherein the officials guard the public interests while handing out even justice to inventors.

A practitioner of forty years before the Patent Office recently said to the writer, that amid the mass of mechanical, scientific and legal technique, by statute bound up with the daily activities of the Patent Office, quite generally he has found there, splendidly exemplified, the human element and the spirit of helpfulness.

As a striking example of efficiency and sturdy integrity in free government, the service modestly rendered each workday in the United States Patent Office, should be known and be heartening to earnest men everywhere.

RESULTS EXPRESSED IN NUMBERS.

As perhaps a not inappropriate conclusion, a diagram is appended, showing graphically the increasing number of patents granted, and consequently inventions disclosed in the Patent Office, during what must ever remain a wonderfully interesting epoch in our industrial development. This diagram covers the eighty years from the establishment of the Patent Office, 1836 to 1915.

A public disclosure of nearly one and one quarter million new inventions in eighty years will be conceded a fair return made by inventors for the very limited rights which they have enjoyed. Besides, there is a surplus of many millions of dollars accumulated in the United States Treasury, for the credit of the Patent Office, from fees paid in by applicants for patents.

THE MOST FERTILE FIELDS OF INVENTION.

	Patents.
Carriages and Wagons	37,728
Clasps, Buckles, Buttons	18,772
Harvesters	15,006
Plows	15,907
Mills	18,803
Machine Elements	15,062
Bufiders' Hardware	15,826
Games and Toys	12,164
Locks and Latches	11,930
Mills, Grinding, etc.	18,803
Railways	11,347
Railway Rolling Stock	15,462
Seeders and Planters	11,059
Water Distribution—Mains and Pipes, Cocks and Faucets, Pipe Couplings, etc.	21,592
Wood Working	10,060

	Patents.
Locks and Latches	11,930
Washing Machines and Other Laundry Appliances	11,385
Buckles, Buttons and Clasps	18,772
Steam Engines	11,907

SOME OF THE MOST PROLIFIC INVENTORS.

	Patents.
Edison	977
Elihu Thomson	617
Francis H. Richards	847
Edward Weston	299
Charles E. Scribner	437
George Westinghouse	340

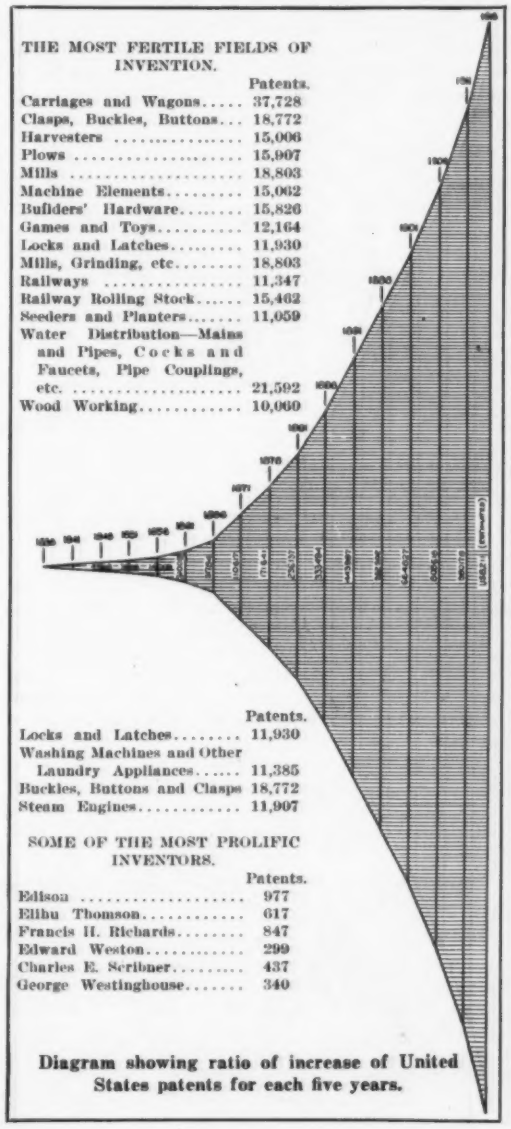


Diagram showing ratio of increase of United States patents for each five years.

Engineers' Difficulties With Tropical Telephones

TELEPHONE troubles are far from rare in England, says *The London Daily Telegraph*, but they are mild in comparison with those that occur in the tropics. British users of the 'phone should be thankful that the engineers of the home system have only an occasional gale or snowstorm to contend with; their plight would be very sad if instead of these comparatively rare disturbances, they had frequently to meet such obstacles to the satisfactory working of the telephone as are enumerated by Mr. W. Llewellen Preece in his most interesting paper read recently before the Institution of Electrical Engineers on "Telephone Troubles in the Tropics."

It appears that the troubles in the tropics arise from such causes as damp, vegetation, animals and insects, and inefficient native labor. The heat is in itself not responsible for much trouble, but when this is combined with an atmospheric humidity varying between 80 and 90 per cent it is possible to appreciate the reasons for the telephone engineer's complaints. When, in addition, it is realized that this damp heat produces a marvelous growth of vegetation—so thick that along the sides of the country roads there are actual walls of green leaves, perhaps 80 feet to 100 feet in height, so dense that it is impossible to pierce through without getting one's clothes torn off the body, and growing so rapidly that it may be cut back one day and grow as high again in the ensuing twenty-four hours; when again it is learned that insect life is as prolific as the vegetation, and sometimes even more trying, then one is in a position to understand the difficulties and to sympathize with the tropical engineers.

As a matter of fact, these are not the only troubles. Lightning has a virulence unknown there. The electrical state of the atmosphere has an effect on the human nerves which seriously disturbs one's temper. Even wild animals do their best in some places to increase the engineer's labors. For instance, in some parts it is not unusual to have a mile or two of lines wrecked by giraffes, elephants, or monkeys.

As regard insects, Mr. Preece has some remarkable facts to bring forward. These creatures will attack both instruments and lines. The spider is a real pest all over the tropics; it delights to retreat into the telephone case, and there build for itself a nest, so that it is no uncommon experience to find instruments entirely put out of action owing to the diligent work of this insect.

To circumvent the insect plague it is essential that these telephone cases should be sealed up as closely as possible. The switch-hook should carry a brass plate which keeps the slot in which the arm works entirely covered. It is also desirable to have no terminals above the instruments, but to take the conductors through holes into the case and seal up these holes.

The prevalence of white ants makes it hopeless to use wood poles to carry the lines, as in a very few years the insects demolish the whole of the interior of such poles. The arms, on the other hand, are often made of this material, for the white ant will not work its way up fifteen or more feet of iron tube to reach these arms, and in some countries most excellent hard wood is obtainable locally. The normal type of overhead construction now employed in most tropical countries is fairly well standardized. The poles used are either of a type with wrought-iron taper tubes and cast-iron bases, or of the Hamilton type, which are built up of tubes of riveted sheet steel.

Overhead line troubles would, of course, be abolished if underground cables were used, but when it is a frequent occurrence for some subscribers to be situated as far as twenty-five miles from the exchange this system would call for such a high subscription as to make the proposal entirely prohibitive.

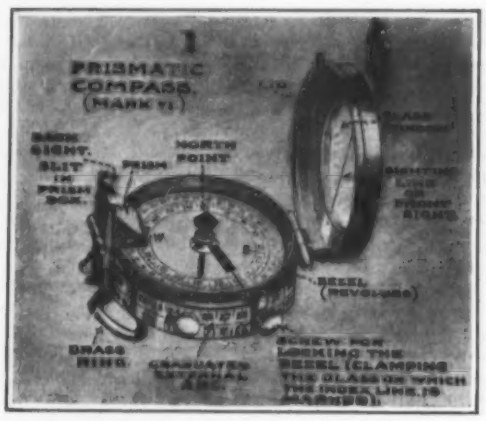
Thus the use of overhead lines must be continued and means devised to make them less likely to be attacked by insects. It has been discovered that whereas insects will nest in porcelain insulators—which are dark inside—they refuse to inhabit the transparent glass insulators, which, if made of the oil type, should, it is suggested by Mr. Preece, bring about considerable improvement in the insulation. Unfortunately, such insulators are not at present commercially obtainable.

The Prismatic Compass*

How It Works and Some of Its Advantages

THE prismatic compass is so called from the prism fitted on the case at the opposite side to the hinge. By means of this prism an observer is enabled to read the figures on the dial when taking a bearing.

The "Service pattern" has a dial of mother-of-pearl, the center being coated with luminous paint for night work. The N. point is marked with a large diamond-shaped figure, and the S. a line, E. and W. being shown in black letters. The dial is graduated with two sets of figures—to 360 degrees—the inner set, for ordinary direct use, divided to 5 degrees; and the outer, for use with the prism (and reversed, for the prism inverts the image), divided every degree. A glance at Fig. 1 will show this dial mounted in its case. It will be noted the lid has a large glass window having a sighting line engraved across its surface. There are two small holes in the edge of the brass rim of this window, so that, should the glass be broken, a horse-hair can be run between them and an extemporized sight vane be utilized. Opposite the hinge of the lid a triangular box containing the right-angle prism is fitted for reading


1
PRISMATIC COMPASS (MARK VI)
BACK SIGHT. SLIT IN PRISM BOX.
PRISM
NORTH POINT
SIGHTING LINE ON PRISM GLASS
REEL (REVOLVING)
BRASS RING
GRADUATED EXTERNAL ARC
SCREW FOR LOOKING THE REEL (CLAMPING THE GLASS BY WHICH THE INDEX LINE IS MARKED).

The prismatic compass (mark VI).

the dial. Over the dial a glass is placed in a revolving bezel. On the glass is painted a black "index" line corresponding with an engraved line on the bezel working over a graduated scale on the outer surface of the box. By this line and scale a bearing can be "registered" for night marching operations.

In taking a bearing, the compass is held steadily, raised to the eye, keeping it quite level, and the front sight (*A* in small diagram shown in Fig. 5—line on glass) and the back sight (*B*—slit on the prism box) are aligned on to the objective *C*. The division seen in the prism cut by the hair line *A* will be the bearing required.

The bearing can now be registered by turning the milled edge bezel until the black index line on glass is over the N. point of dial. The division on the top scale of outside of box which coincides with line is the bearing. At the same time, the direction is indicated by the compass letters on the bottom scale. The bezel is then clamped. On any subsequent occasion, day or night, the same direction can be found by turning the cover back flat (as in Fig. 2), holding the compass in front of you until the N. point on dial coincides with index line. The sighting line on glass and luminous patches in cover point to the objective.

It is not always possible to ascertain the bearing by sight, so the compass is then set by means of a map. This is done by ruling a line through the point of departure to mark the *magnetic* N. and S. line, and a second one to the objective, to mark the line of advance (see Fig. 3)—Departure, London; objective, Godalming).

The compass is laid along the one showing advance, and carefully adjusted by laying the sight of lid and bow ring at back over the line. The index is now shifted until it exactly coincides with the N. and S. line. The compass is then ready for use.

The Value of Birds to Man

AMONG the zoological articles in the Smithsonian Annual Report is one on the value of birds to man, in which the author, Mr. James Buckland, of London, makes the astounding statement that, although man imagines himself the dominant power of the earth, he is nothing of the sort, the true lords of the universe being the insects. For although man has attained predominance over the most fierce and powerful animals and most deadly reptiles, he and his works would be of little avail before an attack of insects, which include a greater number of species than all other living creatures combined. Some 300,000 species have been described, while possibly twice that number still remain unknown.

The author says that these incomputable hordes feed on nearly all living animals and practically all plants, and multiply into prodigious numbers in an incredibly short time. Computations show that one species developing 13 generations a year, would if unchecked to the twelfth generation, multiply to 10 sextillions of individuals; while a single pair of the well-known gypsy moths, if unchecked, would produce in 8 years enough progeny to destroy all the foliage of the United States. One pair of potato bugs, he states, would develop unchecked 60,000,000 in a single season, at which rate of multiplication the potato plant would not long survive.

According to Mr. Buckland's article, insects are quite as astounding in their consuming qualities as in their rate of increase; a caterpillar eats twice its weight in leaves a day, and, in proportion, a horse would consume

Fig. 5.—What the observer sees in the prism-box of a prismatic compass.

This diagram shows in the smaller circle what the observer might see in taking a bearing, holding the instrument as in Fig. 1. The larger circle represents diagrammatically the window. *A*, front sight on window; *B*, back sight slit in prism-box; *C*, distant objective.

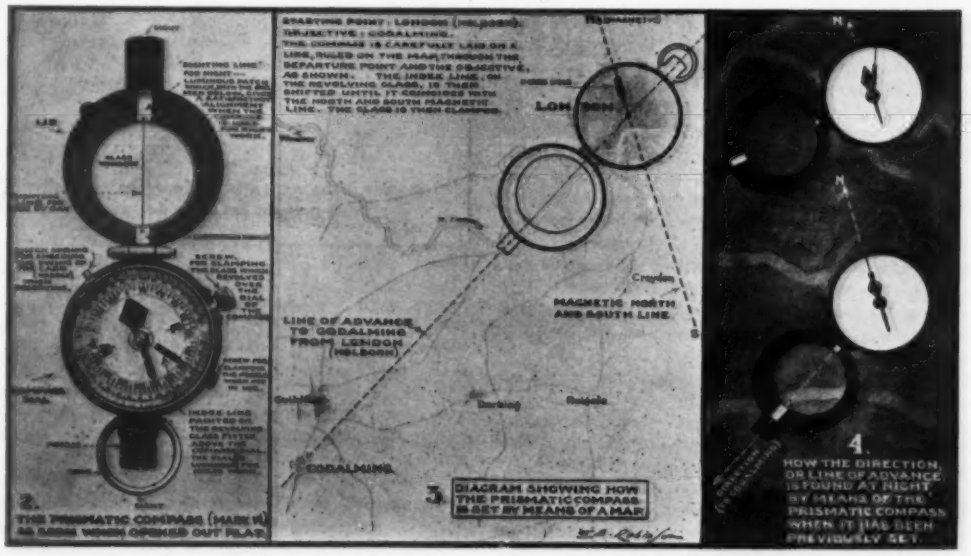
a ton of hay in 24 hours. Certain flesh-eating larvae consume 200 times their original weight in 24 hours; in this manner an infant would devour 1,500 pounds of meat during the first day of its life. It is reported by a specialist, that the food taken by a silk-worm in 56 days equals 86,000 times its original weight. All of which facts show what tremendous destruction insects may cause.

Through its predominating insect diet, and on account of its exceedingly rapid digestion, the bird becomes the most indispensible balancing force of nature; without its assistance, man, with his poisons, the weather, and animals, as well as the parasitic predaceous insects, would be helpless. The author then states how the bird is a benefit to man in a great number of ways; in checking insect invasions, in preserving forests and orchards; their service in the meadows and gardens; their value in protecting live stock, and their usefulness in the preservation of health and elimination of disease.

Remarkable instances of the birds' service to man include the introduction of the English sparrow into New Zealand with the resulting elimination of the thistle and the caterpillar which were ruining the land and crops, and the saving of Australian agriculture from the grasshoppers by the straw-necked ibis, in individual craws of which an average of 2,400 grasshoppers was found. The story of Frederick the Great, wherein he is alleged to have ordered all small birds killed because the sparrows had pecked at some of his cherries, and the resulting lack of fruit but fine crop of caterpillars two years later, proves a graphic lesson. The "Scalp Act" of Pennsylvania, which paid in bounties $90,000 for the extermination of hawks and owls, lost for the State $3,850,000 in damage to agriculture due to the increase of small rodents which resulted. When Montana was free from hawks and owls it became so overrun with destructive rodents, that the legislature offered rewards for them—a task which the banished hawks and owls had performed free of charge. But during the first six months such large sums of money were paid out that a special session of the legislature was called to repeal the act before the State went bankrupt.

In closing, Mr. Buckland makes a plea for the preservation of all birds as a valuable natural resource, stating that if their destruction is not checked, there will be wrought a mischief, a universal disaster, greater than words can express.

The Italian Aerological Service, which has been in operation since May, 1912, probably represents the most thoroughgoing attempt that has yet been made to maintain a daily survey of the direction and force of the air currents at various levels over an aera of national extent. As compared with the analogous German service (*Wetterdienst für Luftfahrer*), which has 21 stations, the Italian service has, in a smaller area, 31, and has thus far published the results of observations on a much more extensive scale. The latest undertaking of the Italian service is a daily bulletin, with charts, showing the winds at various levels over Italy, as observed at 8 A. M. and 3 P. M. by means of pilot balloons and nephoscopes. The service has also published detailed discussions of the observations, which bring out many interesting facts regarding the air circulation at various levels in connection with barometric conditions at the surface. The director of this aeronautical weather bureau (which, appears to be entirely independent of the regular meteorological service of Italy) is Capt. Luigi Matteuzzi.


2.
THE PRISMATIC COMPASS (MARK VI) AS SEEN WHEN OPENED OUT FLAT.
LONDON
Croydon
MAGNETIC NORTH AND SOUTH LINE
LINE OF ADVANCE TO GODALMING FROM LONDON (HOLBORN)
Guildford
Dorking
Reigate
GODALMING
3. DIAGRAM SHOWING HOW THE PRISMATIC COMPASS IS SET BY MEANS OF A MAP.
4.
HOW THE DIRECTION, OR LINE OF ADVANCE IS FOUND AT NIGHT BY MEANS OF THE PRISMATIC COMPASS WHEN IT HAS BEEN PREVIOUSLY SET.

How science aids the soldier in finding his way across country by night—the working of the prismatic compass.

These diagrams should be studied in connection with the article opposite on the prismatic compass. Here it may be added, in continuation of that article, that before the night-march takes place the dial is exposed to daylight (about half an hour before sunset should make it luminous for some six to nine hours). The compass is then used exactly as with a registered bearing (Fig. 4), the sighting-line and luminous patches pointing to the line of advance—Godalming. In the latest form of compass exposure to daylight is unnecessary, as the wonderful substance, radium, has provided us with a new radioactive point that is always self-luminous. The compass-needle, of course, points to the magnetic north, and not the true or geographical pole. The variation in England is some 15 degrees.

* From *The Illustrated War News*, published by *The Illustrated London News*.

Nepal*

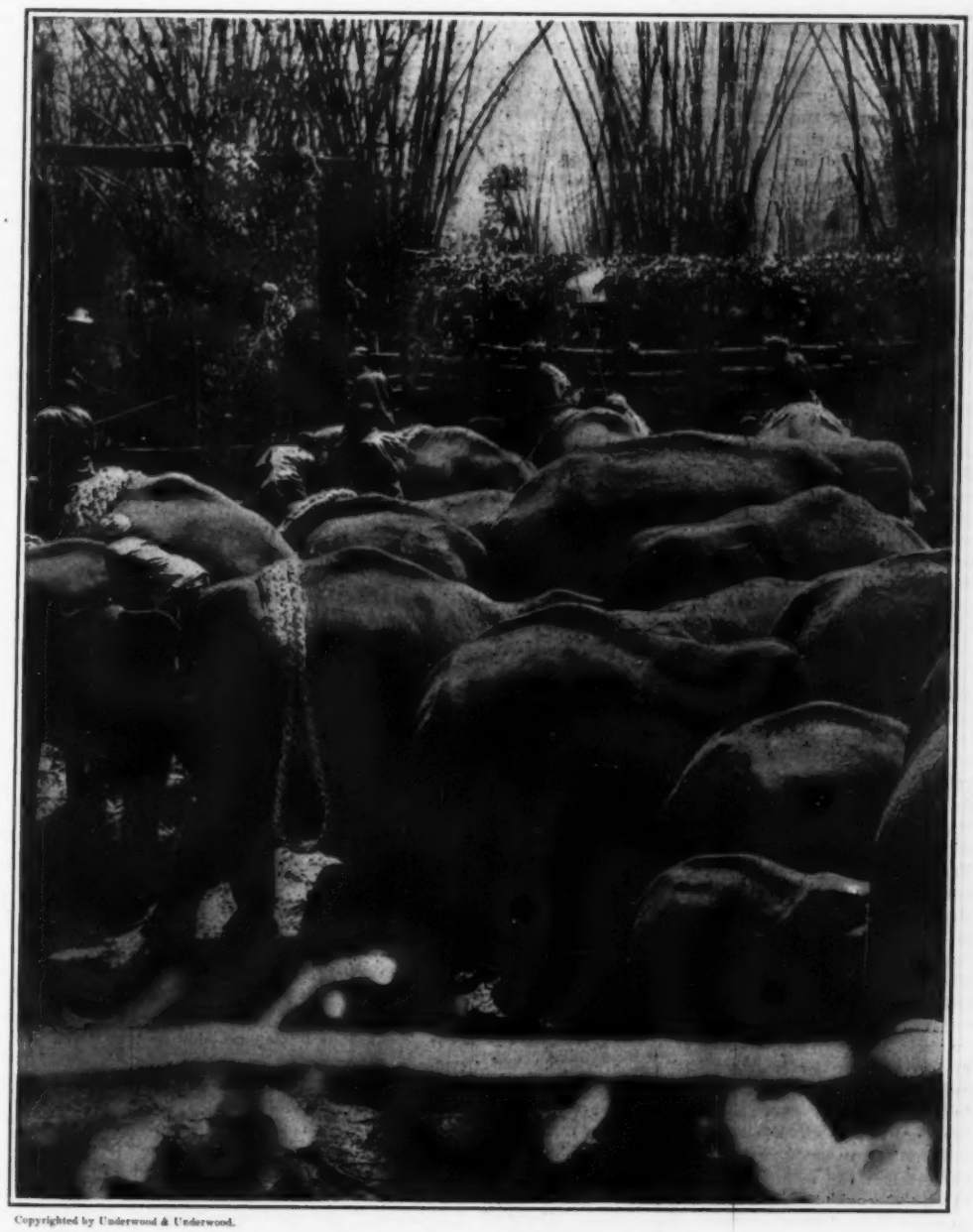
Notes on a Visit to a Country Inaccessible to Europeans

By Henry John Elwes, F.R.S.

NEPAL is unique in this respect, that it remains a solitary instance in the world, of a friendly country which, from political reasons alone, is inaccessible to Europeans. For, though during nearly a century our relations with its rulers have been perfectly peaceful, and latterly even cordial, and though the present ruler of Nepal is a man of European culture, speaking perfect English, and understanding English customs, politics and civilization in a way that few Oriental rulers do, he has rigidly adhered to the policy instituted sixty years ago by the all-powerful minister, Jung Bahadur, and has maintained a system of government which may be best described as a paternal despotism founded on the religion and customs of his people. It is, therefore, impossible for Europeans even to enter Nepal unless specially invited, as we were, by the British Resident at Katmandu, Colonel Manners-Smith, V.C., or by the Maharaja Sir Chandra Shamsher Jung, G.C.B., G.C.S.I., G.C.V.O., to both of whom our most cordial thanks are due for their hospitality and kindness during our too short stay there.

Though our relations with the Nepalese government were not at first so uniformly friendly as they have been ever since the Indian mutiny, when Jung Bahadur came to our assistance with his army, yet we have learned that it is possible to do what has never been done by any other European government—to live as neighbors on a frontier of over five hundred miles without any friction with an Oriental nation distinguished for the bravery and patriotism of its people. And after comparing the conditions which exist in the kingdom of to-day with the state of some parts of Bengal in recent times, I think that we can learn much from the Nepalese in the art of governing primitive mountain races. I will refer those who wish to know more of the country to Sir W. W. Hunter's "Life of Brian Hodgson" (1896), who resided in Nepal as British Resident for many years, and who was the first to make known to science a great number of its animals and birds; or to the "Imperial Gazetteer of India," Vol. XIX. (1908), where an excellent account of the country will be found.

We arrived at Gorakhpur, in the United Provinces, on February 6th, and met Colonel Manners-Smith, who had kindly invited us to join him in camp at Bikna Thori, on the Nepal frontier, to see a kheddah which had been arranged to take place near the locality where King George had such grand tiger shooting when he was in India for his coronation. We arrived at the frontier by rail, and rode up to a camp in the low outer range of hills which inclose a flat, and in some places marshy valley, a little higher than the Terai. The usual system of catching elephants in Nepal differs from that adopted in other parts of India which I am about to describe, and is much more dangerous both to the pursuers and the pursued. It consists of driving the wild elephants into a valley where they can be surrounded, and then, after separating those which it is intended to catch from the herd, overpowering them by special fighting elephants and tying them up separately. In these fights many of the elephants are injured, and fatal accidents to the men employed are not uncommon. But on this occasion the Nepalese government had determined to try the system of kheddahs usually adopted in Assam and Southern India by the Indian government, and had obtained the services of Mr. Armstrong of the Bengal police, and of some of the skilled elephant catchers formerly employed by the government kheddah department at Dacca, which has now been disbanded. This valley and the hills surrounding it are of much the same character as the Dehra Dun, and are covered on the dryer land with forest, mainly composed of sal and other trees often of much larger dimensions than those in the Dehra Dun or in the Sikkim Terai, and in the open and more marshy parts by a heavy grass jungle, which forms a sanctuary for wild elephants, tigers, rhinoceroses, and other game which are preserved for use and sport. At this season the country is dry, cool and healthy, but in the rainy season very hot and malarious. The next day we rode on to the large camp which had been formed for the men employed in the elephant-catching operations on the banks of a river, and found that a considerable number of wild elephants had already been surrounded in a piece of forest about four miles in circumference, bounded on the south by the outer range of hills, on the west by a river whose bed was now partly dry and open, and partly covered by grass and reeds high enough to conceal elephants. The force employed to effect this surrounding consisted of two regiments of Nepalese soldiers directed by the general-in-chief of the Nepalese army. After the wild elephants, about thirty in number, had been surrounded, a line of guards was immediately stationed at posts fifteen to twenty yards apart all round the forest. At each of these posts three soldiers were on guard, who built themselves grass huts, and kept fires burning all night



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A herd of wild elephants penned in a stockade.

to keep the wild elephants from breaking out. Our camp was on the low banks of a river overlooking the scene of operations and close behind the guardline. The first thing to do was to select a position for and build a stockade into which the elephants could be driven, and in this matter the old Jemadar from Dacca, a veteran of seventy years who had spent his life in this work, was the best adviser. He insisted in going alone on foot into the ring where tigers and rhinoceroses were known to be at large with the wild herd, in order to choose the most suitable place. For long experience has shown that wild elephants cannot be driven like cattle, and it became evident, from the frequent attempts which they made at night to break out in a particular direction, where was the best place to build the stockade. This took three days of hard work, as a large number of strong posts fifteen feet long by eight to ten inches in diameter had to be fixed in the ground and supported by struts and cross-bars strong enough to resist the pressure of the herd when driven in. The stockade was a circular space fifty feet across, with a falling gate on one side, suspended by ropes which were cut to let it drop. From the entrance a narrow lane of strong posts extended for two hundred yards, gradually widening into two wings, which opened out like a funnel, and were extended by a line of cloths hung on poles, to form a lead into the mouth of the alley. The walls of the stockade and the lane leading to it were covered by grass and branches so that the elephants might not suspect danger too soon. During the four nights that we were in camp waiting for the stockade to be built, there were constant alarms at various points on the line, as the wild herd, after drinking in the river—where we could often see their backs and hear their trumpeting and screams from our tents—made efforts to find a weak spot in the guard line. On the second night a wild tusker, supposed to be a rogue, broke into the surrounded area from the outside, and made the inclosed herd very uneasy. This tusker was very bold, and one night, just after dinner, he came down and stood within twenty yards of the fires where a crowd of excited men were yelling and firing blank charges in his face, and we quite expected that he would attack and break out. But though we saw him quite close in the moonlight, he eventually retired and the camp became quiet again. On February 12th, after several alarms in the course of the night, which must have been a trying and anxious one for the guards, who had now been for four consecutive days on duty, Mr. Armstrong announced that all was ready, and that about eleven o'clock, when the elephants

* Journal of the Royal Society of Arts.

were generally quietest, the drive would take place. Two platforms had been erected above the stockade into which we climbed, and the driving-party, under the command of Armstrong and the old Jemadar, were mustered. The Nepalese were selected from the most experienced jungle men, and between every two of them one of the Dacca men accustomed to this work was placed. Absolute silence was ordered at the stockade when the party marched off in two lines, which spread out from the stockade and swept the whole of the forest within the guard-line, and when the leaders met on the far side, perhaps a mile away from the stockade, gradually closed in toward it. After waiting an hour or so we heard a great noise accompanied by many shots from the guard-line, which told us that the elephants were on the move, and the noise came nearer and nearer till we thought that the herd must be within the wings of the stockade; but after a time the noise died down, and for an hour nothing more was heard. The same thing happened again, and at last Armstrong came back to the stockade, very hot from his exertions, and told us that the Nepalese drivers were so excited and keen that he could not keep them in order, and that on the first occasion the elephants were on the point of entering the wings but were so frightened by the noise that they broke back. After a consultation it was decided, on the advice of the Jemadar, to remove the cloth screens to another position where the grass was thicker and wait a bit before trying another drive. This was done, and about 5 P. M. a final and successful effort was made. The elephants came on within the screens, and then Armstrong and his men lit grass fires behind them, and by dint of firing and yelling got them on the move toward the alley, into which an old cow first came rushing down. The others followed her, and as soon as they were all within the wider part of the alley the crowd of men yelling and firing rushed them forward in a long line. We could only see their backs as they came down the alley one after another and entered the stockade with a rush. The rope which held up the gate was cut a little too soon, shutting out one or two of the hindmost elephants, but these were determined to follow their companions and forced their way through the gate, which was so hung as to push inward. The whole herd was then inside, and until it was dark they continued to go around and round in a dense crowd, while the men who surrounded the stockade prodded their trunks with spears or fired blank cartridges in their faces when any of the larger ones tried to force their way through. It was very curious to see the way in which the youngest elephants, of which there were three only a few months old, managed to save themselves from being trodden down, by keeping between their mothers' forelegs, and the care which their dams took to protect them. As it was then too late to begin to tie up the animals, we left the stockade at dark to the care of the guards who had now left their posts and come to the stockade. Next morning we returned to see the process of roping and leading out the elephants; but though several of the finest and strongest tuskers were brought into the inclosure the mahouts seemed unused to the work they now had to do in such a dense crowd of elephants. There was not room enough for the noosers to go in on foot, and the constant movement of the crowd surging round and round made it very difficult to get nooses on their feet from the outside. This work requires experience which the Nepalese had not previously had, and from the pictures, which were taken at a kheddah in Southern India where they have more experience in noosing in a stockade, it seems that they are there more adept in what seems a most dangerous work. But though the mahouts had spears with which the prick the trunks of any wild ones which might attempt to touch them, I never saw one offer to do so. Many of the captured elephants now seemed to act very tired and thirsty—as well they might be after such days and nights as they had endured—and we never thought the young ones would have survived; but though it took three days before the whole thirty-three elephants were finally tied up and pulled out of the inclosure, not one was seriously hurt, though several of the oldest were released as not being worth the trouble of training. I will not occupy your time any longer with an account of this process, which has been well described by Sanderson and others. But though native mahouts, who have spent their lives among elephants and have inherited from their fathers a knowledge of their management in health and in sickness which few, if any, Europeans have ever acquired, I believe that a lover of animals who would pay the same attention to elephants that many Englishmen do to horses would learn a great deal which would be valuable in managing the elephants which are still indispensable in the forests of India, and might be even more useful in some parts of Africa.

Ten days later we arrived at Raxaul, a frontier station a little to the east of Bikna Thori, where the Resident has a bungalow, and where he had made arrangements for our journey to Katmandu. The first stage of thirty miles through the level plain of the Terai we made in doolies carried by bearers, and at daylight we found ourselves in the Sal forest near Churia, where the outer range of hills begins. Here we breakfasted and went on horseback over a low rocky sandstone range in which *Pinus longifolia* is a noticeable but not important tree; and passing through a narrow gorge, where in many places the dry river-bed is the only road, sometimes impassable in the rainy season, we crossed an open valley where the cotton trees, *Bombax malabricum*, were of great size. One of which was 120 feet high by 30 feet in girth at 5 feet from the ground, and about 60 feet round the buttresses at ground level.

We then followed the banks of a river along a road practicable for bullock carts and wooded with tropical trees, but not nearly so luxuriant or so varied in its vegetation as a valley in Sikkim of similar elevation would have been. The large white blooms of a shrubby climber called *Beaumontia* were at this season the only striking flowers I saw, and along the road there were but few birds to be seen, as numbers of bullock carts were constantly passing. In the evening we reached Bhimphedi, a large village at the foot of a steep range of mountains over which the path is quite impracticable except for coolies; and here we were met by a party of men with doolies and torches, who surpassed all the bearers I have ever seen in their power. For to carry a man of my weight in the dark up a winding path on a gradient of thirty to forty-five degrees and covered with rolling stones was a work I should hardly have thought possible till I experienced it; and they only stopped for a few moments to relieve each other on an ascent of over 2,000 feet. Near the top of this mountain, the Resident has another bungalow at Sisagarhi, between five and six thousand feet above the sea, where we found dinner and beds ready. Next morning we had a fine view over the outer hills, and found rhododendrons in flower and evergreen oaks all around us on the dry grassy hillsides, reminding me far more of Chakrata in the Northwest Himalaya than of anything in Sikkim. Next morning we went on with the same doolies, and after crossing the ridge at about 7,000 feet descended on foot by a very steep rocky path through a fairly thick forest on the north side, where, though some orchids appeared on the trees and climbing plants and ferns were numerous, the whole aspect of the vegetation was utterly unlike the much damper forest at similar elevations in Sikkim. At the foot of this mountain we found ponies kindly sent by the Maharaja, and turned northwest up an open dry valley, cultivated in places with wheat and mustard as winter crops in small terraced and irrigated fields, and passed over bare grassy downs on which a plantation of *Pinus excelsa* had been made. The villagers' houses were built of brick and roofed with tiles, mostly two-storied, the upper floor being inhabited by the people, and the lower used for cattle and stores. A small primrose, *Primula Munroei*, a Polygonum like *P. vaccinifolium*, and a small stemless *Tragopogon* were the first signs of spring. Crowds of Hindu pilgrims on their way from the plains of India to a religious festival at Katmandu were on the road, nearly all walking, but a few riding or carried on coolies' backs. Among them were large numbers of women, who caused my companion, new to India, to remark that this was the only country he had ever seen where it was possible to pass thousands of women without a smile on the face of one of them. The contrast between their resigned and melancholy expression and the smiling faces of the Nepalese women, who crowd the bazaar and as porters welcome the stranger on his arrival at Darjeeling, is very striking. In the afternoon we ascend another steep ridge through forest mainly of evergreen oak, and at the top had our first view of the great open valley of Katmandu with the snowy mountains in the background. The great open valley terraced and cultivated wherever possible, with the city of Katmandu in the middle of it, and bare mountains covered with brown grass and scrub on the south exposure, formed a scene which, though beautiful in itself, was so unlike and so very inferior in grandeur to the scenery of Sikkim that I could hardly believe I was only two hundred miles to the west of that enchanting country.

Pilgrims, and coolies carrying immense burdens of ironware and European goods on the way to the valley, crowded the path; while those returning were mostly laden with coarse dirty wool from the interior. The last descent was so steep and difficult that a horse-dealer bringing horses from Kabul had some trouble in getting them down. At the bottom we found a good road and a well-appointed pair-horse carriage waiting to take us to the Residency, where we were hospitably received by Colonel Manners-Smith.

It is difficult, if not impossible, for anyone who does not speak fluently the language of a country he visits, and who has no opportunity of conversing freely with the people in their own language, to form a correct opinion of the economic or social condition of its inhabitants, especially when restricted to a very small area surrounding the capital. But after many years of travel in Asiatic countries, including Asia Minor, Siberia, Japan, Formosa, China, Java, the Malay Peninsula, and with an intimate knowledge of Sikkim and other parts of India dating back to 1870, I formed the opinion that the government of Nepal is a form of government well suited to the ideas of Oriental peoples. Though the rulers of Nepal have rigidly kept their country free from European education and commerce, and have strictly adhered to the tenets of their own religion and customs, yet the facts that the people appear healthy, happy, and not over-taxed, that the standing army is one of which any Oriental state may be proud, and that law and order prevail to an extent which has kept the relations of their people and ours peaceable and friendly for a very long period, prove that such a form of government has advantages which modern reformers cannot overlook. And when the internal condition of Nepal is compared with what it was in Brian Hodgson's time, when bloody quarrels among the ruling chiefs and members of the Royal Family were common, one must admit that for a country where the land suitable for cultivation is insufficient for the maintenance of an increasing population, and where the natural products offer few openings for trade or manufactures, Nepal is in many respects fortunate. I cannot help remarking the difference which exists in the friendly relations between British officers, soldiers and tea planters, and their Nepalese soldiers, comrades, and laborers, with the attitude and comparative want of sympathy between Europeans and most other natives of India. One cannot work long with Nepalese without acquiring a respect and liking for their pluck, endurance and cheery goodwill under conditions of danger and hardship; or ignore the devotion they show to Englishmen who treat them properly and understand their ways. As pioneers on the northeast frontier of India they have no rivals, and though there is much difference between the various castes and tribes, yet, on the average, I prefer them to any other natives of India with whom I have had to do. The fact that we are able to recruit and maintain no less than twenty battalions of the best native infantry in India entirely drawn from Nepal, and that the laborers employed in the large and important tea industry of British Sikkim have been almost entirely supplied by Nepalese immigration, proves the importance to British India of our friendly relations with Nepal.

The Maharaja has done much to improve the native breeds of cattle, and has imported from India and Europe bulls of various breeds with this object. He is also trying to improve the sheep with rams from my own flock. The native sheep are a large coarse wooled breed, similar to those kept by the Nepalese on the frontier of Sikkim and commonly brought to Darjeeling for mutton, and are able to endure the cold and wet climate of the higher ranges better than the improved breeds in England would probably do; but below, about 6,000 or 7,000 feet, it is not a country generally suited to sheep, though goats are numerous.

Buffaloes are kept in large numbers in the Terai, and are valued for their milk and meat, but do not seem to be used for agriculture as much as in Formosa, where on steep hillsides, lying with a slope of twenty to forty degrees, narrow irrigated terraces are ploughed by buffaloes, which are much more active and better climbers than their normal habitat would lead one to suppose.

In Nepal, as in Sikkim, most of the cultivation is done by hand labor, and irrigation is general wherever water can be brought. In the dry weather it was impossible to judge of the crops, but the rice and maize stubble did not indicate such good soil as in Sikkim; and I believe that the area of land available for cultivation at healthy elevations is in most parts of the country too small to allow much increase in the population, who emigrate in increasing numbers to Sikkim and the frontier districts of Assam.

Both sexes from their childhood acquire the habit of carrying very heavy loads on their backs, especially the tribes of the higher levels, who carry on nearly all the trade between Nepal and Tibet in loads of from 80 to 200 pounds over paths that would be impassable to beasts of burden.

The forests of Nepal do not seem to have received from the government anything like the attention they deserve, as the growing scarcity of timber in Bengal and the United Provinces must make them valuable in future if they were properly protected. Neither tea nor camphor, both of which would no doubt grow as well as they do in Sikkim, are grown, though I believe that camphor might become a valuable and profitable product.

Whether the necessity for increased revenue to pay for the many kinds of European goods which the government and upper classes are requiring in larger quan-

tities, will eventually induce the government to pay more attention to trade and industry than they have done at present is a problem that time alone can solve; but up till now no permission has been given to any foreigners to embark on such enterprise—Nepal for the Nepalese being the fixed policy of the past and present rulers.

Of the natural history of Nepal I can say little from personal observation, because we were not able to visit the mountains of the interior, where are found a great variety of birds and animals which have been described many years ago by Hodgson, who, during his long residence, employed native collectors to procure, and native artists to draw, all that he could get. In this way most of the rarer animals which inhabit the central Himalaya were first made known to science, but of their distribution little is known. There are a number of genera represented in the northwest Himalaya by species different from those which are found in Sikkim and Bhutan, and it would be very interesting to know where these species meet, and whether they overlap and interbreed. But the mountains nearest to the valley, where alone the Resident and his friends are allowed to go, are too low, and so little virgin forest remains, that their fauna and flora are much poorer than those of Kumaon, Garwhal and Sikkim. In the Maharaja's grounds at Katmandu we saw three living deer which had been caught on the frontier of Tibet and of which little is known to Europeans. One I believe to be a female of the species known as *Cervus Wallichii*, of which a fine male, now in the Zoological Gardens, was presented by the Maharaja to King George when in India four years ago. Another is a male of *Cervus affinis*, which inhabits the high forest country in the northwest of Bhutan, and whose antlers are sometimes brought by natives to Darjeeling, where it is known as the Shou. The third is *Cervus Thoroldi* = *C. albirostris*, discovered by Dr. Thorold in the country northeast of Lhasa and not known to be a native of Nepal.

In the Maharaja's palace, which is a large modern building in European style, I specially admired the very delicate carving which is done by native carvers in a wood known as Dar, *Bökmeria regulosa*, Wall.; this is a very close-grained red wood, easy to work, and found along the lower hills, but not usually attaining a large size. The immense quantity of fine woodcarving, with which the older houses of Katmandu are adorned, shows the talent of the Newars in this branch of art, which, however, seems to be a dying if not a dead industry, as there are now no professional carvers except those employed by the Maharaja, and no shops where such beautiful work can be procured. The same seems to be true of the workers in copper, brass and silver, who now work only to order, and I cannot help thinking that these arts might be encouraged by making an outlet for their work in British India, where there is now a good demand among tourists and residents for the fine metal work brought from Lhasa, much of which is similar in character to that of Nepal.

To most travelers the buildings, temples and ancient monuments of the towns of Katmandu and Bhatgaon are probably the greatest attraction in Nepal, as their architecture is unique.

We must remember that although at the present day Buddhism and Brahmanism both obtain in Nepal, where the two are indeed inextricably confused, it was not always so. When the Buddha made his first converts in the Himalayas, five hundred years or so before the Christian Era, he found Brahmanism the established religion of Nepal. Therefore, just as birds, under the memory of the species for a once warm home, go northward with the spring into Arctic lands, so these poor Hindus move northward to a home of the infancy of their faith.

I have seen many pilgrimages—pilgrims from the farthest confines of the Roman Church drawn to Lourdes for healing; pilgrims on their way to Mecca; Russians from Siberian wastes come down to the Jordan for the dipping of the shrouds that will enwrap them when they die; Hindus from far Ceylon bathing in the sacred river at Benares—but this pilgrimage in Nepal was certainly in some way the most remarkable. Of those thousands of struggling men and women many were infirm and aged, some so worn by the hardships of the weary way that they would probably not live to see their homes again; a few who had money to spare for this advantage were huddled up in baskets on porters' backs.

The Gurkha, as far as Nepal goes, only dates from the eighteenth century. We are here concerned with the Newar, the original inheritant of the country. The Newar is Tibetan, as the Gurkha is supposed to be Rajput, in origin. His are the arts, the industries, the agriculture. All, then, that we see here in these pictures—architecture, woodcarving, metal work, stone—is Newar in conception and workmanship. And although the pagoda in principle is Chinese, its detail is so entirely different from that which we are accustomed to see in works on China, its decoration is so vigorous, so unconventional, and so true to life, that Nepal may be said to have a distinct art of its own, and that art expressed by great artists.

The Newar is primarily an artist in wood, and his control over that medium is astonishing. The decorative forms of windows, doors or plinths are not confined to shrines or to houses of the well-to-do; it is a principle throughout the land, some of the poorest country cottages having most beautiful workmanship. The picture of a wayside cottage shows the same form of horseshoe-headed window, with its lattice, that we later find elaborated in the wonderful buildings of the town. For although geometrical design forms the basis of this work, it is not "left at that," as in the lattice screens of India and Burma, but, where the money was sufficient, is overlaid by a complicated tracery of foliage, flowers or animal subjects. These are not only in their main lines true to Nature, and therefore quite recognizable (notice the mango over the doorway), but are arranged in a well-defined scheme of composition in the most artistic way. The ability to portray well-known animals is common even to primitive people; the reindeer of the Cave-men are real reindeer, the antelopes of the Bushmen are unmistakably Oryx or Sable, as the case may be. But these people, each in their day, were the *children* of the world, and their drawings, like all drawings done by children, insisted on detail as the child's eye sees it.

The Newar artist had advanced a long step farther; he was no nursery artist—he had "arrived." He knew exactly how to generalize, how to insist on the big features that gave his plant or his animal its recognizable character and individuality, and how to drop all those details that did not tell. And this was equally true whether he worked in wood or in metal; less so, perhaps, in stone. For all that, when form demanded it, he could be as strictly conventional as a Greek. As examples of this, notice the conventional lotus on the well-head and on the capitals of the monumental columns.

Two types of temple are noticeable in these pictures—the Chaitya type and the Pagoda type. The first is the Buddhist form, the other is Nepalese Hindu. These latter are not found, I believe, in India, if we except one that stands out unmistakably among the temples of Benares—the pious gift of a Maharaja of Nepal. It will be noticed that each story of these pagoda temples is supported by long wooden struts. Recourse to such a device to support an overhanging plinth or other structure is elsewhere common enough; a familiar instance is that of the Ponte Vecchio. But the Newar has gone one better than the Tuscan, for he has carved each strut elaborately from end to end.

The shrines would take a paper to themselves. They are of wood, metal, and stone. In noticing their extraordinary wealth of decoration, it is necessary to realize that nothing is introduced without a meaning; that each detail, decorative as is its effect, has a distinct and definite significance in the religious sequence of a people's worship.

The doorway of the Durbar Hall in Bhatgaon is, of course, well known as one of the greatest achievements in metal in the world. It is of copper overlaid with gold. It is, indeed, a thing of fascination; the folds of its serpent seem to writhe, the lizard on its lintel might be darting in the heat.

But of all the remarkable and beautiful features of the streets of these Nepalese cities, nothing holds the attention so strongly as the monumental statues. I do not know whether these are absolutely peculiar to Nepal, or whether they are also met with in Tibet; the writer, at least, had never seen anything like them. They are sculptured portraits of various rulers who built the temple in front of which they stand. First there is a simple base, then a square stone pillar, perhaps 30 to 50 feet high, then a beautiful capital of lotus pattern. On this is placed sometimes a throne of copper gilt, based on animals—elephants or others. On the throne the Newar king is seated, with the cobra or a gilt umbrella as a canopy above him. In some examples his family are about him; in others he sits upon no throne, but kneels in an attitude of adoration before the temple of his gods. No description could adequately convey an idea of the extreme and beautiful dignity of these monuments. What they owe to their surroundings it is impossible to say; they belong to Nepal and not to Trafalgar Square. There are, at any rate on the Maidan of Katmandu, some very fair equestrian figures of Maharajas that are of western making; and to come upon these after the others was to change the sublime for the commonplace. Seen where they were, these columns of the rulers seemed structurally, decoratively, spiritually, and in their beautiful repose, a final word in art.

The Combustion of Coal in Boiler Furnaces

In a preliminary report on a series of experiments conducted by J. K. Clement, J. C. W. Frazer, and C. E. Augustine on the factors governing the combustion of coal in boiler furnaces at the Bureau of Mines, the following practical points are noted. These suggestions, together with a detailed account of the first of a series of experiments on the above subject, will be found in Technical Paper No. 63, issued by the Bureau.

The efficient use of coal is dependent on proper furnace design as well as on proper firing and control of the furnace. Many furnaces are built without regard to the special characteristics of the fuel to be used, with the result that for years fuel has been burned in an inefficient and wasteful manner, and so as to aggravate the smoke nuisance.

In the design of boiler furnaces the requirements of efficient combustion have been made secondary to many less important factors, largely because of a lack of definite information about the processes of combustion.

The combustion of coal may be considered as taking place in two stages: (1) Distillation of volatile matter and partial combustion on the grate, and (2) combustion in the combustion chamber of the gases rising from the grate. In order that the second stage of the process may be complete, it is essential that the combustible products given off from the fuel bed remain long enough in the combustion chamber to be entirely burned before they become chilled by contact with the relatively cold boiler surface. If the combustion space is too small the gases will pass out of it only partly burned, and a loss in heat and a lowering of efficiency will result.

Combustion is influenced by many factors, the most important of which are the following: The volume and shape of the combustion chamber; the kind of fuel used, especially the amount and character of the volatile matter and rate of firing; the rate of heating the fuel; the air supply; the rate at which air is mixed with the combustion gases in the furnace; and the temperature of the combustion chamber.

The composition, as well as the amount, of volatile matter given up by a given coal varies greatly with the temperature to which the coal is heated and the rate of heating. The influence of temperature on the amount and composition of the volatile matter distilled from various coals has been studied by Porter and Ovitz of the Bureau of Mines.[1] They found, for example, the following values for the volume of combustible gas given off in ten minutes from 10 grammes of air-dried Pocahontas coal:

RELATION OF TEMPERATURE OF FURNACE TO VOLUME OF COMBUSTIBLE GAS.

Temperature of furnace, deg. Cent...	600	700	800	900
Volume of combustible gas, cubic centimeters	50	670	1.570	2.300

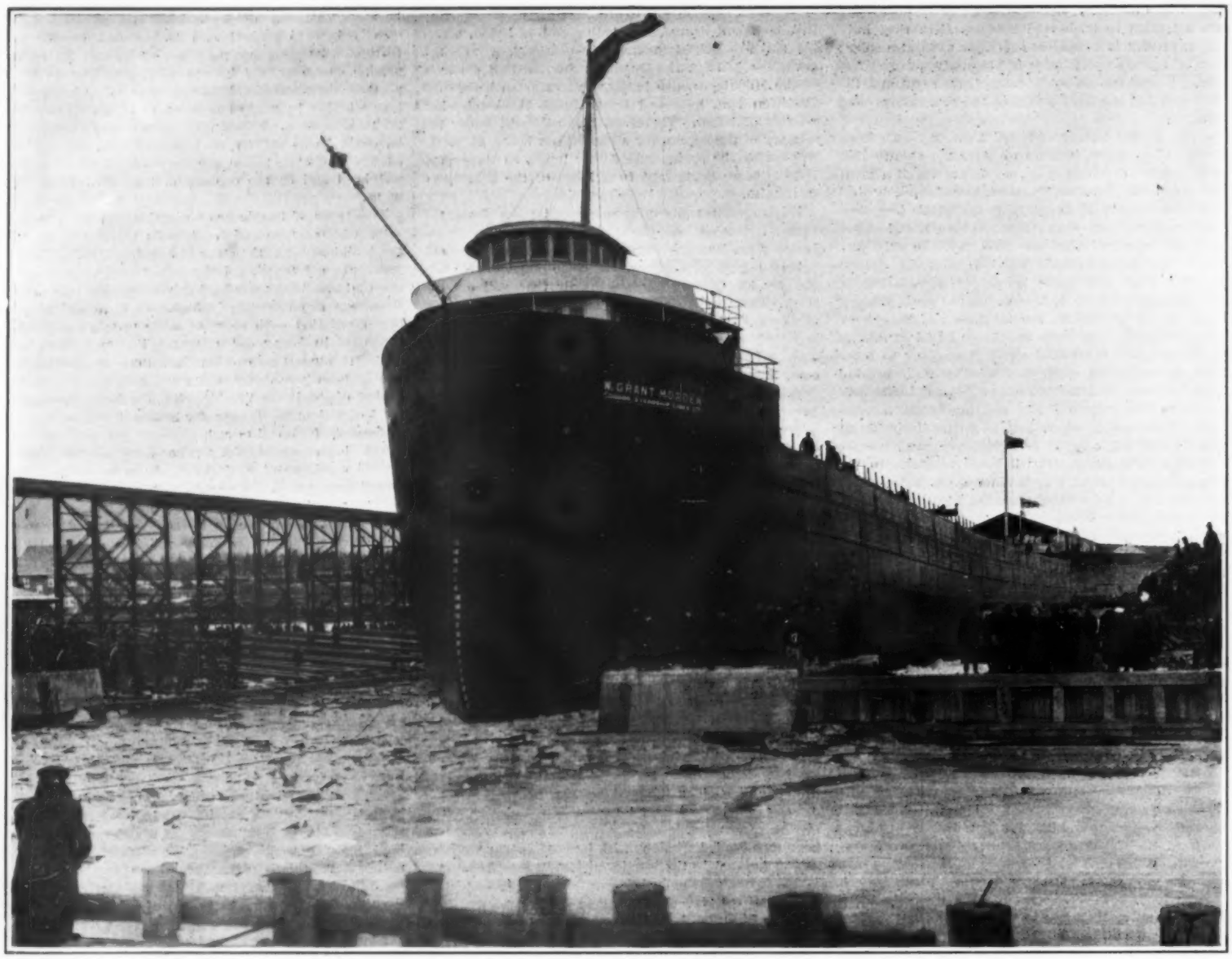
The amount of tar produced increases with increase of temperature in about the same proportion as does the volume of combustible gases.

The heavier constituents of the volatile matter, especially the tar, do not burn readily and require more time for combustion. The higher the temperature at which distillation takes place, therefore, the greater is the amount of volatile matter drawn off and the more difficult is the combustion of its constituents. A rapid rate of heating of the fuel produces a rapid evolution of slow-burning volatile matter. A slow rate of heating results in a gradual and uniform liberation of volatile gases, which are more readily combustible. One advantage in the use of the automatic stoker over hand firing is that in the automatic stoker the coal is heated gradually through the temperatures at which distillation takes place, whereas in hand firing the green fuel is thrown on the incandescent fuel bed and thus heated from room temperature to the furnace temperature.

In the tests described in this report the supply of coal was regulated automatically and the rate of heating was constant for each rate of firing. In a future investigation it is planned to vary the rate of heating the coal and to study the relation between the rate of heating and the volume of combustion space required.

With the type of stoker used in the tests the coal is fed continually to the grate, and with proper regulation of the speed of the stoker engine the thickness of fuel bed may be kept fairly constant. In the tests with Pocahontas coal the thickness of bed carried was about six inches. No attempt has been made to study the relation between different thicknesses of fuel bed and the space required for combustion. There is ample evidence at hand to show that excessive thickness of bed favors the formation of CO by the reaction: $CO_2 + C = 2CO$, the reaction that takes place in the gas producer. Increasing the thickness of the fuel bed, therefore, not only reduces the combustion space above the bed, but produces greater quantities of CO, and thus increases the volume of combustion-chamber space required.

[1] Porter, H. C., and Ovitz, F. K., The volatile matter of coal: Bull. 1, Bureau of Mines, 1910, 56 pp., 1 pl., 9 figs.



The largest built freight carrier on the Great Lakes, just after launching.

Freight Carrying on the Great Lakes

Where Immense Quantities of Grain, Ore and Coal Are Moved in Bulk

By Day Allan Willey

WHAT is claimed to be the largest bulk freight steamship in the world has been constructed at Port Arthur, Canada, to carry grain between ports on the Great Lakes, and has a capacity of 585,000 bushels, or approximately 20 trains of 30 cars each. It is 625 feet long, 59 feet beam and 32 feet deep, with a water bottom, and side tank 5½ feet, extending from the keel, up to the main deck, and from the collision bulkhead back to the engine bulkhead, and divided by a center keelson, side bulkhead and solid floors into fifteen watertight compartments, which may be flooded or pumped out individually, as conditions may require.

The construction was on the Isherwood system, consisting of longitudinal frames with transverse sections of plate and angle, spaced every 12 feet. The cargo hold, 436 feet in length, is divided into six compartments by five solid steel bulkheads, entrance to which is gained by 38 steel hatches, opening from the spar deck, and spaced 12 feet centers. These hatches are 9 feet wide by 41½ feet long, and are covered with sectional steel plate folding covers, operated by steel cables from two deck winches, and clamped down with a patent hatch fastener especially designed for this type of cover.

The power plant includes one vertical, triple expansion engine, with cylinders 24, 39, 65 by 42 inches stroke, having an indicated horse-power of 2,000 at 85 revolutions per minute. Steam is furnished by two Scotch boilers 16 feet diameter by 11½ feet long with induced draught, working under the pressure of 170 pounds per square inch.

The steering engine is of the direct acting type, with 9- by 9-inch cylinders, operated with telemotor gear.

The electro lighting plant consists of two 15 kilowatt generating sets, installed in the engine room, with separate circuits fitted for the different parts of the ship, including electric mast head, stern and side lights, so arranged that should any of these lights go out, the fact will be instantly noted in pilot house by pilot lights installed therein, which are lighted automatically. One of the two 10- by 36-inch whistles is also electrically controlled.

A feature very seldom found in the freight carriers is an ice machine large enough for refrigerator coils and ice tank of two tons capacity. The spar deck forward is fitted up for passengers, and is finished in full panel of mahogany, containing four staterooms and bath, opening off a large reception room, which communicates by stairs to an observation room on the forecastle deck above.

The captain's quarters are in the "Texas," and are finished in quartered oak, including office, a bedroom and bath, with a stairway leading into a pilot house directly overhead. The forward crew's quarters are located on the main deck, and are finished in oak with white pine ceilings, each room containing berths for two people, with exception of the mate, who has a separate room. These quarters include bathroom, shower bath and large reading room for the sailors. The after deck house contains a private dining room for passengers, finished in quartered oak with white pine ceiling, and a dining room for officers and a mess room for the crew.

The chief engineer's quarters consist of office, bedroom and bath, and forward of him are the assistant engineer's, oilers', and firemen's rooms in separated quarters on starboard side. On the port side are located quarters for deck hands, stewards, the galley, and ice box.

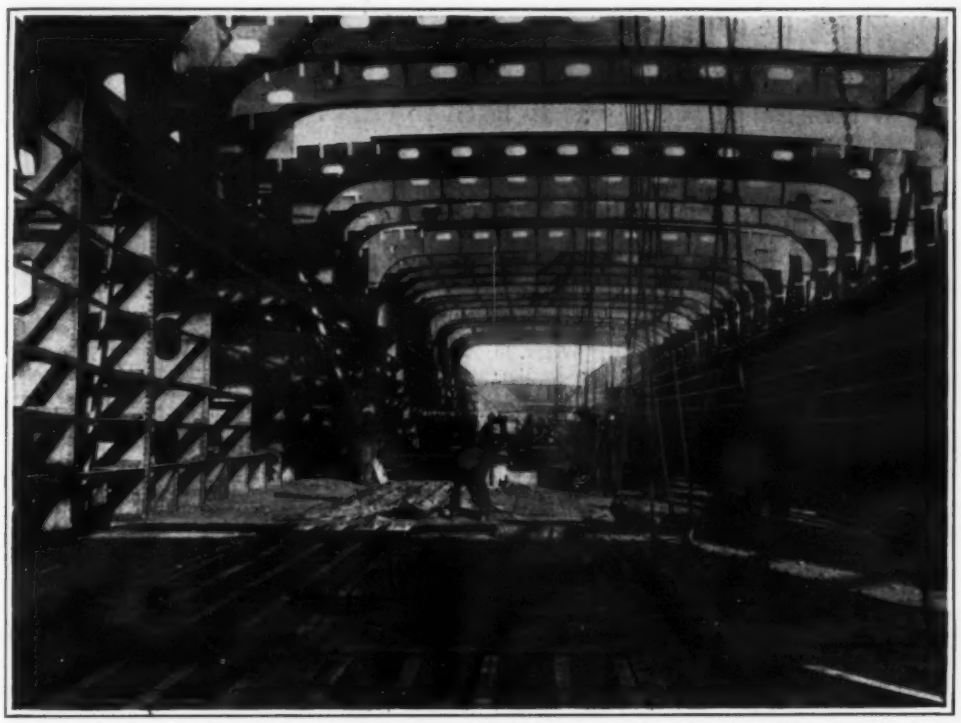
British Shipping Tonnage

STATISTICAL tables issued by Lloyd's Register give the merchant vessels of the United Kingdom on December 31st, 1914, approximately as follows:

	Vessls.	Gross tons.
Steam	12,854	19,145,146
Sail	8,203	864,384
	21,057	20,009,530

This is the first time, says the *Shipping Gazette*, that the figure of 20,000,000 tons has ever been reached, and it was attained after five months' effort on the part of the second greatest maritime power to wipe, if possible, our merchant shipping off the seas. To make the impressiveness of the figures still more clear, let us add that the tonnage referred to is that registered in the United Kingdom alone, for it does not include that registered in other parts of the Empire; and that the corresponding figure on December 31st, 1913, was 19,604,900 tons.

Consequently, during a year, which includes five months of ocean warfare, the register of the United Kingdom has increased by 404,630 tons of shipping. But it is really better than that. There were added 462,107 tons of steam, and removed 57,477 tons of sail. Thus the net gain of 404,630 tons is a much larger addition than it appears, because steam tonnage is more effective than sail, in the proportion of three to one.—*The London Daily Telegraph.*



In the hold during construction, showing arch and longitudinal system of framing used in many modern bulk freight carriers.

Utilizing Wastes in Canning Pineapples

A FULLY ripened pineapple, of the more desirable kinds, is so delicate that it will not stand transportation for long distances, so there are few regions where this delicious fruit is in its best form; but the perfection of modern canning processes now makes it possible for people anyhere in the world to get the pineapple in a really desirable and satisfactory form.

In the business of canning pineapples Hawaii has taken a leading position, a result of abundant supplies of fruit of a superior flavor, and the most modern and sanitary methods of packing, and the growth of the industry is indicated by an increase of from 2,000 cases in 1901 to over two million cases in 1914. This phenomenal growth of the packing plants has left little time for the study of details, and heretofore there has been considerable waste in the processes; but that this is being corrected is shown by the following notes from a pamphlet on the industry recently published by the Department of Commerce.

Within the last year or two a demand has been created for the cores, which were formerly thrown away. These cores are not unusually stringy or tough in the ripe fruit of the Hawaiian pineapple, and make a much-liked product of the confectionery trade when manufactured into chocolate-coated or glacé pineapple. At one of the factories it was stated that the demand for these cores was greater than the supply and that some attempt had been made to cut the whole pineapple into square strips about the size of the core to correspond with the Singapore chunks. This has not proved altogether successful, however, because the flesh is too tender to hold together after opening the cans and during the process of further manufacture by the confectioners. The cores are usually packed whole, but a few are cut into shorter lengths. They constitute about 5 per cent of the entire pack. One of the larger factories has been unable to dispose of all the cores produced, and this suggests that a proper campaign among the confectioners using pineapple might result in the substitution of Hawaiian cores for Singapore chunks, in view of the superior flavor and texture.

The greatest waste existing up to the present time in packing was from the loss of the juice. The pineapples as brought in from the fields are fully ripe, and the fruit is permeated with a luscious juice, which is pressed out and wasted at every process of cutting and handling by the various machines. The disposition of this juice had become a source of considerable expense during the busy season, and in some of the larger canneries more than 10,000 gallons were daily pumped into the sea. To avoid this expense, several of the factories have commenced bottling the juice. One of the methods followed in the bottling is as follows: After being caught in vessels or troughs placed under the different machines the juice is placed in a press and strainer to separate it from any particles of fruit that are collected at the same time. It is then pumped through aluminium pipes (which are not affected by the acid of the fruit) to a filter through which it percolates. It is then brought to the boiling point in a silver-lined vat, after which it is bottled, sealed, and processed. Great care is taken not to fill the bottles too full. The juice is not sweetened, as it contains about 7 per cent sugar and can be used as a beverage without sugar or water. It is improved by the addition of crushed ice. As this is only a comparatively new product, the quantity so far bottled has not been large. If the market can be developed as rapidly for this product as it has been for the canned pineapple itself, a valuable addition will have been made to the earnings of the various canneries. A promising market for this juice should be found in tropical countries where beverages of various sorts are constantly used, especially in the countries where religious principles have made the inhabitants total abstainers from fermented or strong liquors.

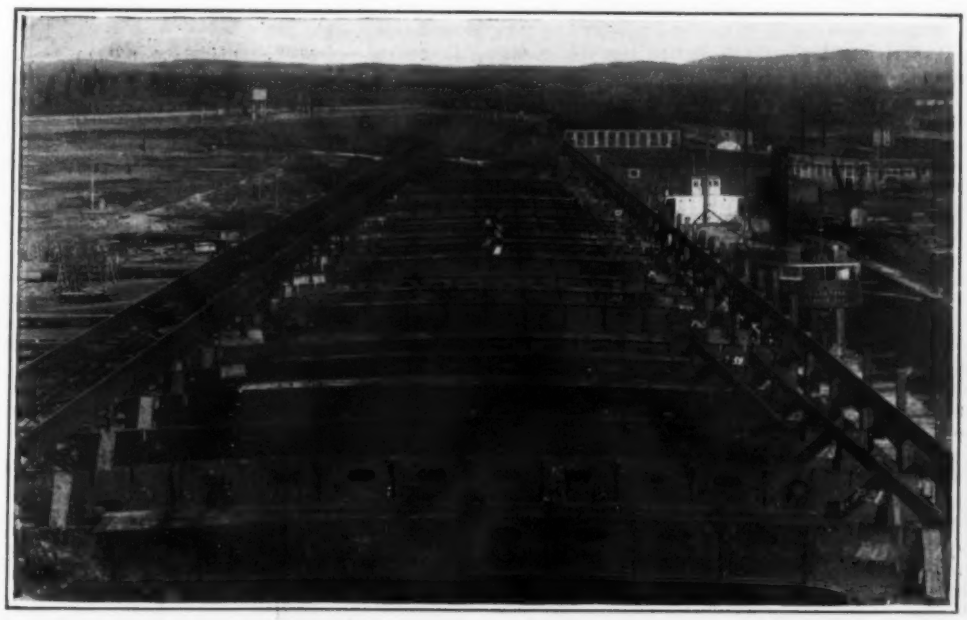
Various experiments along different lines have been made during the last few years in an endeavor to find a use for this juice by-product in the manufacture of alcohol, vinegar, or other experimental products, but the great demands already made upon the various companies in keeping pace with the growth of their factories or in the study of machinery fitted to simplify the preparation of fruit for canning have made it impossible to devote much time to such experiments.

What promises to be a satisfactory utilization of the juice, however, has been evolved by a San Francisco firm of chemists who, in March, 1913, began some laboratory experimentation with the idea of developing processes by which pineapple juice might be made to yield a revenue. A systematic research was conducted, with the result that definite processes and products apparently of a satisfactory quality were developed. One of these was the extraction of sugar from the pineapple juice, which could be used as sugar syrup in canning, thus relieving the pineapple companies of the necessity of purchasing sugar for canning purposes. The first step was to interest capital for the commercial operation of these processes. Several of the largest producers of pineapple juice were approached and an option asked for a period of one year on all the waste juice produced. A small commercial experiment was carried out during June, July, and August of 1913, and sufficient sugar syrup was produced from the juice to can sixty cases of pineapple. This syrup was submitted to the various canners and thoroughly approved as satisfactory. Test cuts were made of the pineapple canned with this syrup and seemed thoroughly satisfactory during the following fall and winter. Contracts were then made with several of the larger factories to deliver all of their waste juice to the new concern for a period of ten years from June 1st, 1915. The agreement carried with it the repurchase from the new concern of all the sugar syrup produced from the waste juice at the market price for refined sugar on the unit basis. The net profits resulting from the recovery of the waste is to be equally divided between the pineapple companies and the new sugar-producing company. The contracts allow the new company the period of one year in which to erect an experimental plant sufficient in size to produce syrup to pack 10,000 cases of pineapple, and if at the end of this experiment the syrup proves thoroughly satisfactory and the cost of recovering is such that the project will prove a profitable commercial undertaking, the ten-year contract will become effective and the new company will be required to handle all of the waste juice produced by the pineapple companies with whom they have made this agreement.

Buildings and equipment costing in the neighborhood of $80,000 are now being constructed and will be capable of handling 50 tons of waste juice per day. The buildings under construction are three in number—one to be 120 by 60 feet, one story high; one to be 60 by 40 feet, three stories high; and a building for a 100 horse-power plant. This factory will handle 50 tons of waste per day of ten hours, and is estimated to produce 5 tons of sugar equal to 10 tons of canned syrup. This new plant is located near two of the largest pineapple-canning establishments in Honolulu and the waste will be carried from them to the recovery plant by a pipe line and the syrup returned to the canneries by the same method. If the results obtained from this $80,000 experiment are thoroughly satisfactory to the producers and the new company, the contracts call for an enlargement of the plant to handle 250 tons of waste per day. As a matter of fact, since the ripening of the pineapple cannot be controlled, it is planned to enlarge the plant so that it will have a capacity of approximately 500 tons of waste per day. This equipment will cost in the neighborhood of $250,000.

No attempt will be made at first to produce in commercial quantities other products that are recoverable from the juice, but the experiments indicate that the sugar for syrup will not be the only product that will eventually be recovered in the new plant.

The experiments of making fiber from the leaves of pineapple plants that are no longer fit for bearing fruit seem to promise a further utilization of the waste. Experiments carried on in Hawaii at the sisal mills produced a satisfactory fiber.



View of the deck framing of the "Morden" during construction. The tracks for the traveling crane used in building are seen on each side.

Atoms and Ions—VI*

A Comprehensive Discussion Especially as Related to Gases

By Sir J. J. Thomson, O.M., F.R.S.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2056, Page 347, May 29, 1915

In the final lecture of his course on the above subject, Sir J. J. Thomson said that on the last occasion he had shown an experiment in which a piece of paraffin was converted into a conductor by the action of polonium rays. In this case we had an insulator rendered conductive by exposure to an agent which was known to be capable of ionizing a gas, and which, it was fair to presume, should accordingly also be able to ionize the molecules of a solid. The conductivity of solids formed a very interesting subject, but there was not time for him to consider more than one or two special cases, which were particularly closely allied to the effects he had discussed in this course of lectures.

One well-known case of the conversion of a solid from an insulator into a conductor was afforded by the Nernst lamp. The filament of this lamp was a mixture of different oxides, and when traversed by a current glowed with great brilliancy, constituting a very convenient source of light for many purposes. The peculiarity of the mixture of oxides used was that its conductivity increased enormously as the temperature rose. Being an insulator when cold, before a current could go through it its temperature had to be raised by artificial means. Once the current got through, however, the heat developed by the very passage of this current caused the filament to get hotter and hotter, till it finally glowed with the greatest brilliancy. The oxides used were specially selected to give this brilliant light, but very possibly the phenomena involved were of the same order as with oxides of calcium and barium. Dr. Horton, working at the Cavendish Laboratory, had measured the resistance at different temperatures of these two oxides, and found the increase of conductivity with rise of temperature was quite parallel to the simultaneous increase in the number of negative particles emitted from a fragment of lime or of barium oxide when heated on a strip of platinum. Such a fragment of barium oxide was conveniently obtained by dropping a little sealing-wax on to the platinum and then heating the latter to a high temperature. Barium oxide was very heavy, and for this reason was added to sealing-wax, which was sold by weight, and hence the cheapest wax was the best for the particular purpose in view. When the platinum carrying such a speck of lime or of barium oxide was heated, negative particles were given off which might serve to carry a current through the lime, and a similar effect might account for the conducfivity of the oxides used in the Nernst filament.

The rate at which these negative particles were emitted from lime and barium oxide had been measured by Richardson, so that the number coming out at different temperatures was known. Dr. Horton had compared Richardson's numbers with the conductivity as measured by himself at corresponding temperatures, and found a close agreement between the two. There was thus considerable evidence that, at any rate, part of the conductivity of the oxides was due to the liberation of these negative particles. An interesting point was that the emission of these particles was very feeble if metallic calcium or barium was used in place of the oxides, from which the number emitted was many thousand times as great as from the metals. Apparently the emission depended on, or was increased by, the mutual presence of two substances having a considerable chemical affinity one for the other.

In this connection he might, he continued, refer to a question which had been submitted to him by one of the audience, as to why the sulphides of certain metals were much better radiators than were the pure metals. It was known from Kirchoff's law that, unless other besides purely thermal effects intervened, the sum of the light emitted and the light reflected from any body depended only on the temperature, and not at all on the nature of the body. This sum constituted the so-called "black-body" radiation. Hence, if a body was a very good reflector, it would only have to emit a little radiation on its own account, while if dull, as when tarnished by sulphide, it would not reflect so much, and must therefore radiate more. He was informed, however, that the difference in the radiating power of the two was much greater than could thus be accounted for. If so, the phenomenon was a very interesting case of what was called chemical luminescence, in which we got radiation from a body at quite low temperatures. For example, phosphorus glowed even at ordinary temperatures. It had also lately been established that a solution of hydrogen peroxide in contact with certain substances would give quite an appreciable illumination. These were cases in which the light did not obey Kirchoff's law, but was drawing upon other sources of energy, in addition to the purely thermal. In the case of lime oxide, there was the possibility of chemical action going on. Barium had, it was known, two oxides, and it was quite possible that calcium possessed the same property, and this might account for the differences observed between the oxide and the pure metal. There might, in fact, be some chemical action going on between the calcium and the oxygen, and similarly, with the sulphides, there might possibly be decomposition of one sulphide and formation of another, or some other form of chemical action might be taking place. In this way there might be local temperatures in excess of the average, some few molecules having very high velocities, though the mean was very much less. In considering radiation, it was important to remember that a few molecules at a very high temperature were much more effective than a lot at a low temperature. Hence, if chemical action caused a few molecules to have a temperature in excess of the normal, the net radiation would be in excess of its ordinary value.

The foregoing was, he said, merely a suggestion, but the observation in question appeared to bring this question of chemical luminescence into a more definite form than hitherto, the treatment of the subject in the past having been more allied to cookery than to chemistry. One experimenter discovered one instance of it, and another worker another example, no very definite connection between the two being established. In all known cases, however, oxygen was invariably present. It was believed by some that even flint sparks were examples of chemical luminescence, due to the oxidation of the freshly exposed surface of the flint, and it was asserted that the cracking of flints was associated with a strong smell of ozone. Local increases of temperature would mean not merely a very great increase in the radiation, but also a change in its character, since the hotter the radiating body, the bluer the light it emitted, the center of gravity of the spectrum being shifted toward the violet end. Hence, in dealing with cathode rays, the light was bluer the faster the particles.

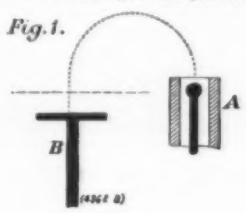
The communication by electrified particles of their charges to metal or other bodies with which they came in contact was not, the speaker continued, so simple a matter as might be expected. It was easy to say that on coming into contact the charge was given up, but a good deal had to be effected during the exchange. A positive particle was one which had lost a negative charge, and when such a particle came up to a metal plate it meant that, in order to become neutral, it had to get out of the plate a negative charge. Similarly, a particle carrying a negative charge had to stick this charge on to some atom or molecule which already had its full complement.

It was thus *à priori* conceivable that this process of getting rid of a charge and fixing it on to a metal plate was not so easily effected as was often imagined.

Many years ago, the speaker, when working with a highly exhausted bulb, had earthed a pool of mercury lying in the bulb with a view to removing electricity from the tube. The arrangement did not work as well as had been expected, electricity being still found in the tube after the lapse of several hours. The mercury, therefore, had not been able to discharge the gas. Recently Franck and Hertz had shown that different substances possessed different powers of absorbing electricity from these particles. Some atoms and molecules seemed quite incapable of retaining one of these negative particles if the velocity were less than a certain critical limit.

The principle of their apparatus is represented in Fig. 1. The cathode was a heated wire placed inside a tube, as indicated at *A*, to prevent particles getting out laterally. From the hot wire negative particles were driven off by the potential of the wire, and followed a curved path through the gas to the collector-plate *B*. Above this plate was a wire gauze, which could be connected up to the negative pole of a battery, and would thus oppose the passage of the particles to the collector. It was found that the particles shot off from the cathode, in spite of the collisions they had to encounter from the gas in the tube, made their way to the collector-plate even when the gauze above the latter was at a negative potential of as much as 6 volts (in the case of certain gases), the total potential between the cathode and the collector-plate being, say, 12 volts. In all the thousands of collisions they had experienced, many of the particles had not succeeded in sticking on to the molecules encountered. The effect was most marked with argon, neon, and helium, with which there was practically no communication of energy between the particles and the molecules. On this head it should be borne in mind that inter-communication of energy between colliding elastic particles was easy when both colliding bodies were of the same size. When, however, one body was more than 1,000 times that of the lighter body, the latter bounded off with practically unchanged energy, each particle retaining what it had before the encounter. Hence, if a negative particle passed through the midst of one of these inert gases, the collisions would merely check its rate of progress toward the collector-plate; but as the particle lost none of its energy in the collisions, it finally arrived at the collector-plate, belated, but with practically the whole of the energy due to the difference of potential between this plate and the cathode.

Fig. 1.



When the inert gases were, however, replaced by oxygen, then at every collision the particle lost some of its energy, and when it ultimately arrived at the collector-plate, did so with only a small fraction of the energy due to the fall of potential, having retained practically none of the energy given to it during its passage. Hence, the only way to obtain negative particles moving with much energy through oxygen was to reduce the number of collisions by reducing the number of oxygen molecules present, otherwise the energy would be knocked out of the particles as fast as it was acquired. With argon, helium, and neon, on the other hand, the number of molecules present did not matter to the same extent. Though the particle might take a long time to get through a dense crowd of helium molecules, when it finally did arrive, it carried with it all the energy it had acquired in falling through the potential difference between the electrodes. It was thus possible to get luminous effects with helium, neon, and argon at pressures impossible with oxygen. Possibly if oxygen could be completely eliminated, similar results might be obtained with other gases as well as with the three named.

To illustrate how easily luminous effects were obtained with neon, the lecturer took a tube filled with neon, and having a little mercury in it. The tube had a number of constrictions, and on inverting the tube, the friction of the mercury falling through the constrictions electrified the walls, with the result that the neon glowed brightly with its characteristic light.

From this point of view, it appeared, Sir Joseph proceeded, that certain special properties of neon were closely associated with the behavior of its atoms, which, when struck by a negative particle, did not pick up any energy from the latter.

If other bodies resembled neon, it would be very difficult to get electricity into or out of them. If, for instance, metals resembled neon to any extent in this regard, the formation of double layers would be obvious. If there were a difficulty in getting electricity out of an electrified gas, the result would be that the surface of the metal would get charged up with a double layer. If the gas were positively charged, the molecules would stick close up to the surface of the metal, their condition being masked by the negative electricity immediately induced on the surface of the metal. The two electricities would, however, not combine, and the positively charged molecules would possess the potentiality of getting away again. This formation of double layers was a frequent source of difficulty in experimental work with gases at low pressures, the gas being liable to get loose again, giving rise to local creeping of the electricity.

*Reproduced from *Engineering*

Again, the attempt was often made to produce a potential in a gas by shooting it through electrified wire gauze, on the assumption that all particles that passed the gauze would acquire the potential of the latter. This, however, would not be the case if a double layer formed on the wires. The danger of a finite difference of potential between the gas and the gauze was, no doubt less the higher the potential of the latter; but the speaker believed that in some experiments errors of as much as 12 to 15 volts had arisen in this way. The danger was a real one, and, in the case of small potentials, might be serious.

Another problem was, what happened when a gas was ionized by the removal of a negative particle. Was the molecule left behind intact, or did we get sometimes the molecule split up into atoms as the result of the shock, so that we had as a result the charge carried by atoms, and not by molecules? For such a smashing of the molecules ample energy was available, and the question was, did it happen? Experiment showed that at low pressures it did. An investigation into the nature of the positive rays showed that the carriers might be all kinds of things. Some were atoms, others molecules left intact, the shock having been insufficient to split them up, and, in addition, various queer compounds were found among the carriers. It might be asked whether this variety was due to the method of production. In the discharge-tube there were, besides the negative particles, large positive systems, and it might be thought that the latter alone were capable of smashing up molecules into their component atoms, while the negative particles when they collided merely detached a charge.

To test this the speaker had adopted an arrangement by which the number of negative particles could be enormously increased in comparison with the positive carriers. If the negative particles were incapable of splitting up the molecules, the final analysis—by the positive-ray method—should show a much larger number of molecular carriers than before. The method adopted to increase the number of negative particles was to use as cathode a wire heated by an independent current. By increasing the temperature of the wire the number of negative particles emitted could be enormously increased. A photograph of the positive rays was then taken, first with the cathode cold, and next with it at a high temperature, and the two compared. This comparison showed little difference in the proportion of atomic and molecular carriers, but, if anything, the heating of the cathode slightly increased the proportion of charged atoms. This experiment afforded strong evidence that the negative particles could themselves split up the molecules into atoms, and that to effect this it was not necessary to have the big positive carriers. Not only this, but the particles were also able to split up these molecules in all kinds of additional ways. Thus, when water was decomposed by dissolving a radium salt in it, the gases liberated contained notably less than the proper proportion of oxygen. In fact, in some experiments Debierne had got nothing but hydrogen, and a subsequent examination of the water showed this to contain peroxide in solution, so that the oxygen liberated by the negative particles emitted by the radium had gone to oxidize the water, acting thus in quite a different fashion from that which occurred with other methods of decomposing water. The speaker thought that the queer combinations found among the positive rays must be brought about in a similar way, the results often being such as could not be effected by ordinary chemical reactions. Sometimes more than one negative particle was knocked out of an atom. The most exaggerated case known to the speaker was afforded by mercury, where in certain cases as many as seven negative charges were removed from the atom.

Fig. 2.

Thus, Fig. 2 represented a positive-ray photograph of mercury. All the lines shown were due to mercury atoms. In the case of the lowest line the atom had lost one charge before reaching the plate, while to get the uppermost curve seven charges must have been knocked out. Moreover, a comparison of the relative strength of the different curves led to the conclusion that the whole of the seven were knocked out in a single collision, and not successively.

Safety in Good Lighting

WHILE a very conspicuous advance in lighting methods has been made by progressive manufacturers, notably in the iron and steel industry, there are still a large number of manufacturers who seem to regard the lighting as an expense to be reduced to the lowest possible minimum.

The economic value of good illumination, aside from accident prevention, is evident when we consider the greater facility with which an employee can work under good illumination, and the greater accuracy with which gages can be read and tools set.

One large manufacturer, on investigating his lighting conditions, found certain departments in which, during the winter months, the operatives were practically idle for about an hour a day solely on account of darkness.

Good artificial illumination can be furnished in such a factory for eight hours a day at a cost equivalent to about five minutes of the time of the workmen benefited. This illustrates the extravagance of poor lighting.

The question of safety as influenced by illumination presents two phases: First, the prevention of accidents; and second, the preservation of eyesight. While these two phases are often closely related, there are many conditions in which they are entirely independent of each other. The phase of accident prevention is illustrated in the case of the foundry or other shop where cranes or other powerful machinery are in operation.

The liability of crane and elevator accidents is very much reduced with proper lighting.

In the foundries and yards of a plant, it is practically impossible, even with safety committee inspection, to eliminate irregularities under foot. If not illuminated these may readily cause falls, with resulting injuries; and in foundries where molten metal is carried and hot metal abounds, they may often cause serious burns.

Even though guarded to the fullest extent, powerful machinery—in which materials are machined and fashioned into articles of commerce, and in which the arms and limbs are as readily crushed—presents a menace unless the operatives are given an opportunity to see and thus avoid the danger points.

There is practically no manufacturing operation which can be carried on without accurate visual inspection. Some of these operations produce considerable strain even under good illumination, and to require their performance under poor illumination is certain to result in more or less rapid impairment of vision.

It has been found by observation that the most common defect in factory lighting comes from excessive glare and absence of diffusion. Glare is usually caused by bright lights in the field of vision. This may emanate from the light source directly or may be deflected to the eye by a glossy surface; it can also be caused wherever excessive contrast of intensity appears in adjacent fields of vision. The dazzling effect is not only unpleasant, but interferes with seeing. Under continued exposure, eye strain and even permanent injury to the eye may result.

Lights intended to illuminate stairways have been so arranged that, on descending, one could hardly see where to step on account of the glare. Such conditions are conducive to bad falls, whereas if the eyes were properly shielded from the glare, a lower intensity would have been ample.

The unshielded light hung over a machine is a common source of eye fatigue. The glare may not be very evident at first glance, but when the workman's eyes have been subjected to such light for a long time, discomfort and inability to see are the result. The proper correction should be to shield the light by means of a proper reflector, and as such a reflector would tend to direct more of the light upon the work, the working intensity would be increased; so in many cases it is possible to reduce the size of the lamp, or better yet, to relocate the lamp so as to enlarge the area illuminated.

When a light cannot be removed entirely from the field of vision, its brilliancy should be reduced by means of a diffusing globe or reflector, so as to increase the apparent size of the light source and reduce the contrast between it and the background. This has the additional advantage of reducing the sharpness of shadows in the illumination, a result which is of considerable importance in rendering the various parts of the machine or object readily discernible.

Glare received from specular reflection of glazed paper, desk tops, polished metal, etc., often induces eye trouble, headache, and other indispositions, though the sufferers may not be aware of the cause. The remedy is to change the relative positions, so that the reflected light is kept out of the eyes as much as possible, and to enlarge the dimensions of the light source.

Another defect commonly found in industrial lighting is improper distribution. This may be due to too wide a spacing of light units. Under this condition some parts of the room are insufficiently lighted while other parts may have more light than is necessary.

Improper direction of light may illuminate the wrong side of the machine, leaving the important parts in shadow. If the bright parts are near the shaded ones whatever illumination may fall upon the shaded portion is rendered less effective by contrast.

Unsteady or flickering illumination is always objectionable; both on account of discomfort and inability to see. Such variation should always be avoided, whether caused by the units themselves or by the light passing through moving wheels, etc.

Since the purpose of the lighting is to enable the operative to see, good illumination cannot be prescribed without a knowledge of the use it is to receive. In order to plan the lighting of a factory properly, one should be familiar with the processes employed, the arrangement of the machinery and the work tables, as well as the quality of the product manufactured. Practice has established certain methods of lighting which, if properly applied, are satisfactory for the different processes of manufacture. Thus we know approximately how much illumination is necessary for the ordinary grade of work performed on a lathe, as well as the desirable direction. As far as possible, therefore, the experience gained in well-lighted factories should be utilized in planning any lighting installation.

The practice in factory lighting has developed along a few fairly definite lines, which may be designated as localized lighting, general lighting, combined general and localized lighting and localized general or group lighting.

Localized lighting originated with the low-power portable or semi-portable lighting units. These were under the control of the individual workman, to be placed or shifted wherever he desired. Such lamps were commonly used without reflectors and produced small patches of uneven illumination, as well as more or less glare. In many cases lighting with these lamps is now being supplanted by other methods.

There are, however, certain operations which require light inside of a small cylinder or other inclosed space; or where very high intensities are required over small areas, and for these no other method is as practicable as localized lighting. For such conditions, the lamp should be equipped with a reflector to shield the workmen's eyes and reflect the light in useful directions.

General lighting is provided in three principal ways, which are known as direct, indirect and semi-indirect lighting. Direct lighting, depending upon the equipment, may have excessive brilliancy or any degree of diffusion. It is used to a much larger extent in factory lighting because factory ceilings are seldom good reflectors. Direct lighting units are less affected by dust accumulations. The indirect and semi-indirect give excellent diffusion, and are often applied with good effect in offices and drafting rooms when light ceilings are available.

"Combined general" and "localized lighting" is often desirable. With this, a low general illumination is supplied by large units and more intense localized illumination at particular points by low-power units. The localized lighting may be supplied continuously or temporarily as needed. For example, in lighting automatic machinery, a moderate illumination may be sufficient at all times except when a machine is being inspected, set up or adjusted, when a localized light may be needed.

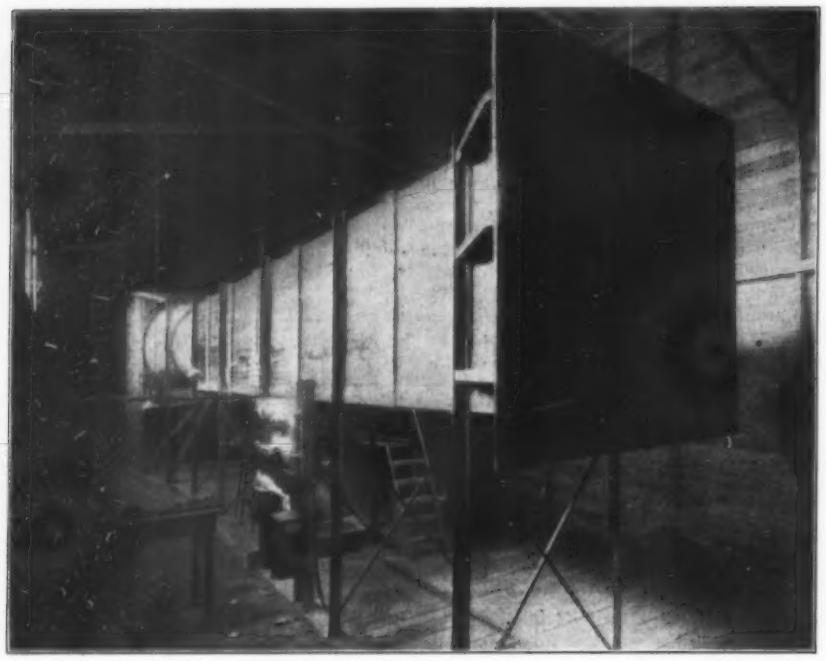
"Localized general" or "group lighting" is a recent practice which has sprung up since a range of intermediate sizes of lighting units has become available. This practice differs from general lighting in that, instead of striving for even intensity throughout the room, lamps are arranged to give higher intensities and correct direction of light at the machines or tables and a lower intensity at intermediate points. It differs from localized lighting in being planned so as to give some illumination, sufficient for the needs, in all parts of the room. It is, therefore, an intermediate practice between the extremes of localized and general lighting. Its application is extending very rapidly, since it meets effectively and economically factory requirements for a large portion of the ordinary manufacturing processes and shop buildings.

Each of these various methods of lighting has some field in which it is to be preferred to any of the others. The selection depends upon the character and construction of the building, the process of manufacture, the source of energy available and various local conditions. —G. H. Stickney, in the *General Electric Review*.

Scientific Aeronautic Research*

The New Aerodynamic Laboratory of the Massachusetts Institute of Technology

By J. C. Hunsaker



Suction end of wind tunnel.

AIR CRAFT have become in the last few years primarily war material, and as such, are designed to meet definite specifications of performance. Five years ago the supreme test of an aeroplane was whether it could fly or whether it could not fly. Now we inquire how fast and how slowly it can fly, what is its rate of climb, useful load, and radius of action? For example, for military uses, armies require a slow endurance machine for strategic scouting which can make raids into the interior of an enemy's country. For tactical scouting over the field of battle, where enemy aeroplanes must be evaded, an army requires a scout of great speed but limited radius of action. Such a machine must have speed and climbing ability superior to that of the enemy units. A third type called a "fighting aeroplane" is necessary to drive off enemy scout aeroplanes. Such a machine must combine the greatest practicable speed and climbing rate with the extra weight of an armored body and a machine gun with a gunner. The performance required for such a destroyer is fixed by the probable ability of enemy scouts to elude it. A fourth type of military aeroplane may soon be developed for the purpose of bomb-dropping. Here the designer would be required to produce a machine able to transport great weight over a long distance.

In all the cases mentioned above the entire military value of the aeroplane lies in its performance, and the burden is thrown on the designer to produce a machine to meet all requirements. Just as in naval architecture the problem is a compromise between the conflicting claims of speed, armor, armament and radius of action.

In view of the necessity for designing aeroplanes to possess given qualities, a designer must guarantee performance. A desired type can, of course, always be reached by building a series of machines but this procedure is extremely costly in time and money, and requires a pilot to risk himself in experimental flights on under-powered and unstable machines.

The problem of aeroplane design involves so many variables that it is often impossible to arrange experimental flights so that changes are made in but one variable at a time. The peculiar conduct of an experimental machine may often be blamed on any one of some half dozen features of its design, and as a result the tests lead only to endless discussion.

On the other hand, it is well established that the performance of an aeroplane can be predicted from experiments on a small model, geometrically and dynamically similar. Model tests are easy to conduct and afford the great advantage that radical alterations of the model may be made without loss of time or risk of life. Furthermore, in model testing, the various parts of an aeroplane may be tested separately to determine the effect of each part on the performance of the complete machine.

In naval architecture, a designer has a small model of his ship towed in an experimental model basin. From the resistance of the model, he can estimate the resistance of his ship and so guarantee its speed for a given power.

For purposes of aeroplane or air ship design, it is possible to tow models in air in a similar manner. However, in aeronautics the problem is extremely complex since in flight, motion is possible along the three axes in space, as well as rotation about any of them. In general, the effect of the air on a solid object moving through it requires the measurement of three forces and three couples corresponding to the three axes of space.

Towing experiments become mechanically difficult to arrange, and in view of the high speeds required in aeronautics a long building like a rope walk is necessary. Such tests have been made at the Kiel navy yard in Germany and at the University of Paris. At the latter institution a dynamometer car running along a track carries objects under test mounted on a weighing mechanism. The tests are conducted in the open air and are subject to error due to gusty winds.

If it be accepted that aerodynamic forces depend on the relative motion of air and object under test, it is immaterial whether the object be towed in still air at a given velocity, or held stationary in a uniform current of air of the same velocity. The use of an artificial wind is the "wind tunnel" method, which has come into general use abroad. The doctrine of relative motion is fundamental in mechanics, and discrepancies between results of tests made by the two methods may be ascribed to the probability of errors due to the influence of the car and wind gusts in the towing method, and to irregularity in the flow of air in the wind tunnel method.

The validity of wind tunnel tests depends upon the uniformity of flow of the air. The production of a current of air that shall be constant in velocity, both in time and space, is a difficult problem.

When it was decided to build a wind tunnel at the Massachusetts Institute of Technology for use by students in aeronautical engineering, a study was made of the most successful wind tunnels abroad. The conclusion was reached that the staff of the National Physical Laboratory, Teddington, England, had developed a wind tunnel of convenient form and of a high degree of uniformity of flow. This tunnel was the result of a methodical series of experiments with wind tunnels of various forms, in which the following conclusions were reached:

1. Models should be placed in the suction stream leading to a fan where turbulence is least.

2. A four-bladed aeroplane propeller of low pitch gives a more steady flow than the ordinary propeller fan used in ventilation work, and a much steadier flow than any blower of centrifugal type.

3. The wind tunnel should be completely housed to avoid the effect of outside wind gusts.

4. Air from the propeller should be discharged into a perforated box of great volume, to damp out turbulence, and to return the air at low velocity to the room.

5. The room through which air returns from the perforated box to the suction nozzle should be at least twenty times the sectional area of the tunnel.

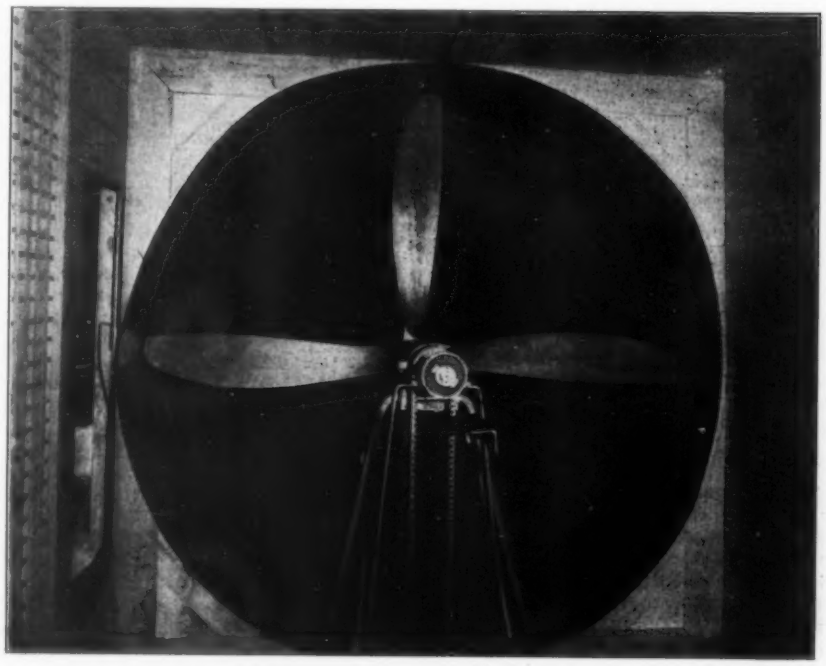
The wind tunnel of the Massachusetts Institute of Technology was built in accordance with the English plans with the exception of several changes of an engineering nature introduced with a view to a more economical use of power. An increase of the maximum wind speed from 34 to 40 miles per hour was thus obtained.

Upon completion of the tunnel an investigation was made of the steadiness of flow. It appeared that the variation of velocity with time and from point to point of the cross section was not more than one per cent.

The wind tunnel proper is a square trunk 16 square feet in section and 53 feet in length. Air is drawn through an entrance nozzle and through the tunnel by a propeller driven by a 10 horse-power motor. Models under test are mounted in the middle of the tunnel on the arm of a delicate balance.

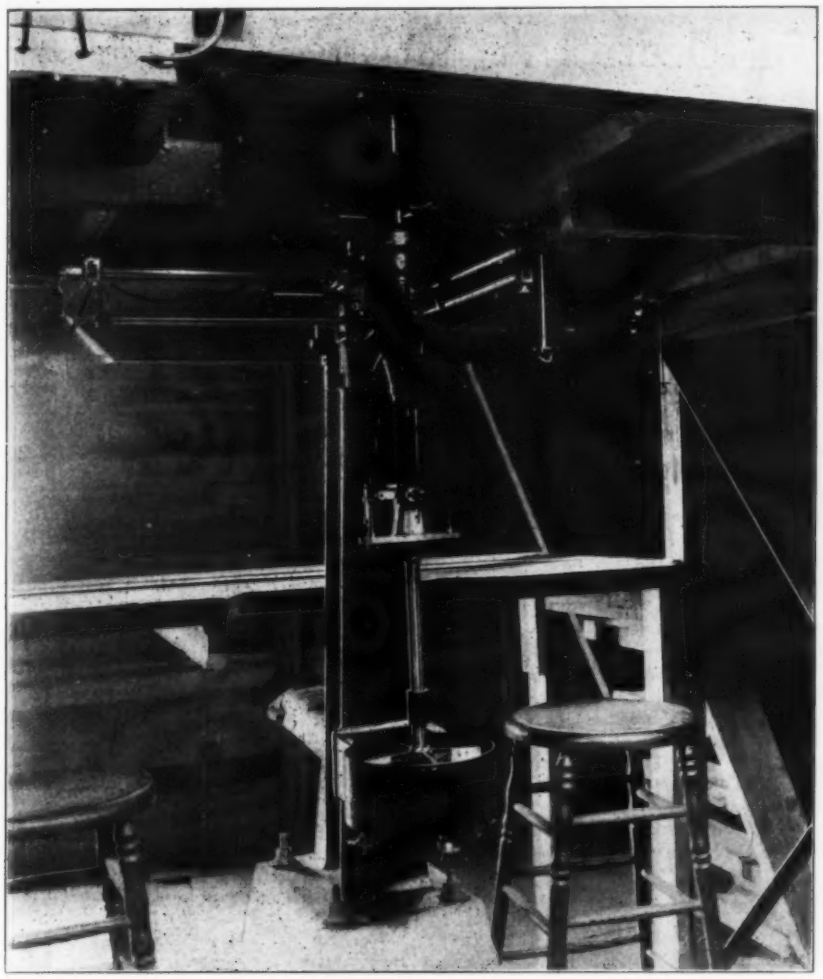
The air entering the mouth passes through a honeycomb made up of a nest of 3-inch metal conduit pipes. This honeycomb has an important effect in straightening out the flow and in preventing swirl.

Passing through the square trunk and past the model under test, the air is drawn past a star-shaped longitudinal baffle into an expanding cone. This cone ex-



Propeller for wind tunnel.

*From *Science Conspectus*.



Aërodynamic balance.

pands in 11 feet to a diameter of 7 feet. The velocity of the air is reduced in passing through the cone and has its pressure increased in accordance with a well-known hydraulic principle.

The propeller is made of black walnut with four blades. It works at the large end of the cone and discharges into the diffusor. The latter is built of wood gratings with holes closely spaced except on the sides facing the propeller which have no opening. The propeller race is stopped by this wall, the velocity of the air destroyed and the pressure raised. The air then escapes through the holes in the diffusor into the room. The current is thus returned through 90 degrees and brought nearly to rest.

Wing model in position for test.

The propeller was designed on the Drzwiecki system, which assumes that each blade section is an aeroplane wing moving through the air in a spiral path. In order to keep down turbulence, a very low pitch and a broad blade were used. To gain efficiency the blades were made thin and, therefore, weak. To prevent fluttering of the blades, the blade sections were so arranged that the centers of pressure of all sections lie on a radial line drawn on the face of the blade. This artifice seems to have prevented the howling at high speed commonly found with thin blades.

The propeller is driven by a "silent" chain from a 10 horse-power inter pole direct current motor. The propeller and motor are mounted on a bracket structure fixed to a concrete block and are hence independent of the alignment of the tunnel. Vibration of the motor or propeller cannot be transmitted to the tunnel as there is no connection.

In order to maintain a steady current of air, the fan must run at constant revolutions per minute, but in order to allow a fine adjustment to obtain and hold any speed, a direct current motor is necessary. To run a direct current motor at constant speed requires a steady voltage. Such is not available. Consequently the following procedure was adopted: A 15 horse-power induction motor is connected to the alternating current power mains of the Cambridge Electric Company. This induction motor is coupled directly to a 12 horse-power direct current generator. The generator supplies current to the motor which turns the propeller. For constant wind speed, the load is constant and hence the induction motor will turn over at constant speed since its slip is a function of load. Variation of voltage in the city mains has small effect on the speed of the induction motor, which runs at a speed proportional to the frequency of the supply current. The generator being turned at constant speed generates constant voltage, and the propeller then runs at constant speed. Due to slow changes in frequency it is necessary to provide variable resistance in the direct current motor field, by the use of which the wind speed can be corrected from time to time. Any wind can be made of velocity between 3 and 40 miles per hour.

The model of complete aeroplane, wing, tail, body or other part is mounted on an aerodynamic balance constructed from the plans of the National Physical Laboratory, England. This balance consists of a cast pillar mounted on an independent concrete block, and the balance proper. The latter is made up of three arms mutually at right angles representing the axes of coordinates in space about and along which couples and forces are to be measured. The model is mounted on the upper end of the vertical arm which projects through an oil seal in the bottom of the tunnel.

The entire upper part of the balance rests on a steel point, bearing in a steel cone supported by the cast iron pillar. The balance is normally free to rock about its pivot in any direction. When wind blows on a model, the components of the force exerted are measured by hanging weights on the two horizontal arms to hold the model in position.

The balance is also free to rotate about a vertical axis through its pivot. The moment producing this rotation is balanced by a calibrated torsion wire.

Special attachments permit the measurement of the force in the vertical axis and moments about the two horizontal axes.

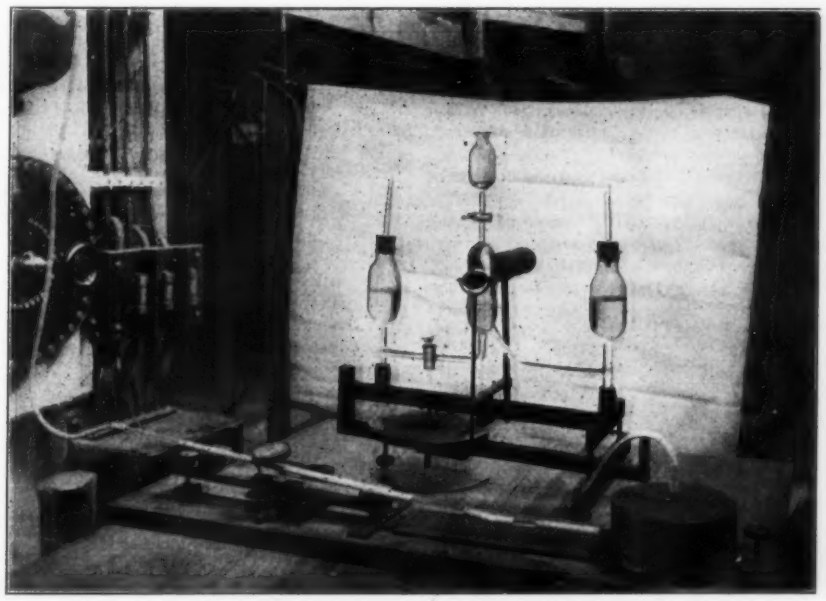
The three forces and three couples acting on any model placed in any attitude can be studied at leisure. The balance is precise to one per cent.

Velocity is measured by means of a Pitot tube which was calibrated on the whirling arm at Teddington. The Pitot tube pressures are read on a Chattock liquid micromanometer. Velocity readings are precise to one half of one per cent.

Tests have been made to determine the lift and resistance of a model aeroplane wing which had previously been tested in England. The results are in excellent agreement and indicate that the English tunnel and balance have lost none of their precision in the rather extensive alterations that have been made here.

The wind tunnel has been in operation since July, 1914, and has been used for comparison of Pitot tubes, determination of the aerodynamic co-efficients for a number of wings, bodies, and miscellaneous objects, for thesis work on aeroplane stability and by students in connection with problems arising in the course of aeroplane design.

It is hoped that in following up design by wind tunnel testing, aeroplane design is being placed on a rational engineering basis.



Chattock micro-manometer (above), Krell mamometer (below).

Development in Electromagnetism—II

A Review of Some Important Problems, and Laboratory Results

By Eugene Bloch, Professor at the Lycée Saint Louis

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2056, Page 339, May 29, 1915

III. ELECTROMAGNETISM AND RADIATION.

THE difficulties just described are not the only ones which the modern theory of electromagnetism encounters. Perhaps the gravest ones arise in adapting it to the experimental facts of radiation. We know that thermal radiation in equilibrium in a constant-temperature chamber, and called "black radiation," has a density independent of the particular body producing it. It is a function only of the wave-length λ and the absolute temperature T. Our theoretical knowledge of this density, u_λ, is expressed by the well-known laws of Kirchoff, Stefan-Boltzmann, and Wien.[24] Our experimental knowledge is expressed by the formula of Planck,

$$u_\lambda = c_1 \lambda^{-5} \left(e^{\frac{c_2}{\lambda T}} - 1 \right)^{-1}$$

This equation satisfies not only the three theoretical laws, but also corresponds to the observed distribution of energy in the spectrum of a black body. This formula reduces for large values of λT to the earlier one of Rayleigh,

$$u_\lambda = c_1 / c_2 \cdot T / \lambda^4.$$

Now, the electromagnetic theory seems to lead almost inevitably to Rayleigh's formula for *all wave-lengths* in flagrant contradiction to experimental facts. The second formula, indeed, does not give a maximum to the radiation distribution curve and makes the total radiation *infinite*. This consequence, which the researches of Lord Rayleigh[25] and Jeans[26] made extremely probable, has been rendered certain by those of Lorentz.[27] According to the latter's researches, the most general equation of an electromagnetic system, based upon the ether, electrons, and matter, by a suitable choice of parameters can be reduced to the Hamiltonian form of the equations of mechanics. The application of the methods of probability and statistical mechanics, especially the theorem of Liouville (which is a consequence of the Hamiltonian form), leads us, then, to consider as applicable to the ether the theorem of the equipartition of energy which also brings us out with Rayleigh's formula.

In order to escape from this blind alley and obtain the earlier formula, Planck invented the hypothesis of the discontinuity of energy or quanta.[28]. According to this hypothesis, the molecular resonators cannot exchange energy with the surrounding medium except in whole multiples of the same elementary quantity (quantum), $h\gamma$, an amount proportional to the frequency of the resonator. The constant h would be a universal constant. We will not explain here the various forms given to the theory by Planck himself, Sommerfeld, Einstein, H. Poincaré, and others (see articles cited, foot-note 27). We will pass over all the consequences which have been deduced from this hypothesis (theory of specific heats by Einstein, etc.), except those which are purely electromagnetic.[29]

It appears that we need not give up for the free ether the equations and ordinary laws of electromagnetics or the dynamics of the free electron. The modification of the electromagnetic theory which we must make, if necessary, relates only to the relations between matter and the ether; that is to say, with regard to electrons not free, to emissions and absorption of energy, or perhaps to emission alone, which must then be considered as discontinuous.

Brillouin[30] thinks that there is a loophole of escape: Planck's theory rests upon an arbitrary hypothesis with regard to strictly monochromatic resonators having very little physical basis. In giving these up, the complication of the reasoning rapidly increases, but Brillouin thinks that we can probably come out with Planck's formula without recourse to quanta. The result would, however, be inconsistent with the general theory of Lorentz previously mentioned. Possibly we may hope to reach more precise knowledge of the mechanism of absorption about which we know practically nothing, and thence get a loophole for escape. This doubtless will happen in the future.

There is another domain than that of radiation, wherein the electronic and quanta theories are clearly inconsistent, that of the properties of the metals. According to the electronic theory, the thermal and electrical conductivities of the metals, as well as many other of their properties, are due to the motion of free electrons. We may, indeed, derive thus the law of Wiedemann and Franz. Electrons should therefore play an important part in the specific heats of the metals. But, according to the theory of quanta, the specific heat is uniquely related to the uncharged atomic resonators (Einstein). This accounts for the behavior of the specific heats at low temperatures. But the quanta theory has nothing to offer as to the thermal and electrical conductivities. The discordance is, however, decisive. It is perhaps premature to try to reconcile matters until measures of the thermal conductivities at low temperatures have been made, comparable with the excellent ones on the electrical conductivities made by Kamerlingh Onnes[31] at the temperature of liquid air and hydrogen.

IV. THE MAGNETON.

The electron seems to have definitely become one of our physical properties. P. Weiss[32] has for several years, and with increasing success, tried to introduce an element of magnetism, the magneton, bringing to bear upon it an imposing mass of experimental results.

He started from the theory of dia- and para-magnetism built by Langevin.[33] In that theory diamagnetism is explained by the deformation of the intra-atomic electronic trajectories under the influence of an exterior electric field paramagnetism results from the existence of a molecular magnetic moment of certain substances. Weiss has elaborated this theory so as to include ferromagnetism by means of a supplementary hypothesis, that of molecular magnetic fields proportional to the magnetizing force. This idea of an electric field is not new. Through it Ritz[34] developed his beautiful theory of the structure of the series of certain spectrum lines and the Zeeman effect. It led Weiss to formulæ which are well substantiated by experiment not only in the legitimate field of electromagnetism (the variation of the Curie constant with the temperature), but also as to the specific heats of ferromagnetic bodies. It was while looking for such precise experimental confirmation that Weiss was led to the theory of the magneton.

The measure of the absolute value of the atomic magnetic moments of iron and nickel at the temperature of liquid hydrogen, made in collaboration with Kamerlingh Onnes, led at the start to numbers 12,360 and 3,370, which divided, respectively, by 11 and 3 lead practically to the same quotient, 1,123.5. For cobalt the corresponding number was later found to be very close to $9 \times 1{,}123.5$. For the molecule of magnetite the results were more complex and must be divided by 3 to compare them with the atom of iron. These also led to whole multiples of the same number, the factor of proportionality changing abruptly at certain temperatures as if the atom of iron underwent corresponding alterations. The number 1,235, of which all the atomic magnetic moments are multiples, will be called the magneton-gramme, and its quotient by the Avogardo number (the number of atoms per gramme-atom) is the magneton, 16.4×10^{-28}. The properties of a ferromagnetic body are then well explained by supposing that the magnetic moments of their atoms are simple multiples of a magneton. Magnetism will then have a granular structure like electricity.

Interesting confirmations have been made of this theory through measures of various experimenters upon paramagnetic salts or, indeed, upon other bodies. The numbers of Pascal[35] and those of Mlle. Feytis[36] are in qualitative and quantitative accord with the hypothesis of the magneton. As these numbers were calculated with reference to water as a standard, an exact knowledge of the diamagnetic constant of water became necessary. Its measure is difficult and has led to discrepant results. It has been remeasured separately by Sève[37] and by P. Weiss and Piccard,[38] who have reached concordant results close to 0.72×10^{-6} at 20 deg. Cent. The theory of the magneton thus has had the merit of fixing definitely this important constant.

We are obliged to admit, however, that for ferromagnetic bodies the atom does not possess a unique magnetic moment, but has a certain number of different values according to the temperature and the chemical compound into which it enters. All these values, however, have integral ratios. The actual existence of the magneton has been demonstrated in the atoms of iron, nickel, cobalt, manganese, vanadium, calcium, mercury, and uranium. We therefore seem to have here a real, very general constituent element of matter. We may therefore think of adding the magneton to the other known fundamental elementary bodies. The attempt made by Langevin[39] to deduce the magneton from the quantum of Planck will doubtless serve as a stimulus in this direction.

IV. THE PRODUCTION AND NATURE OF GASEOUS IONS.

We will not discuss here the simple, ordinary ions such as originate from the X-rays, radium, the Hertz effect, etc. For several years the accepted theory (Langevin, J. J. Thomson, Townsend, and others) was this: the negative electron, torn from a molecule by the ionizing force, surrounds itself with a cortege of neutral molecules; the residual positive atomic ion does likewise. Thus originate the ordinary positive and negative ions. They are characterized by their mobility K, coefficient of recombination a, and diffusion D. At very low pressures and at high temperatures these assemblages are dissociated little by little to the primitive charged center. We will see that some modification of these ideas will be necessary.

(1) Along the line of theory since the fundamental work of Langevin (Annales Ch. Phys., 1905) several new attempts have been made to explain the order of magnitude of the mobilities and their variations. Among these we should specially mention those of Sutherland,[40] of Wellisch,[41] and of Reinganum.[42] Sutherland, especially, departing from the hypothesis of molecular agglomeration, supposes that an ion is identical with the electron or the primitive atom-ion; its velocity is modified and retarded by the electric action exercised upon the neighboring ions or the molecules polarized by its approach. An apparent viscosity is thus created which explains very well the results of Phillips (see further on) upon the variation of the mobility with the temperature. The actual theory is not unlike that which led Sutherland to his well-known formula for the variation with the temperature of the viscosity of a gas.

It will be perhaps convenient to use the conventions of the older theory, considering the ions as assemblages in perpetual process of formation and disintegration in a kind of dynamical equilibrium; the charged center will then be in turn free and loaded with neutral molecules. We will see that a greater part of the experimental data makes such a convention almost necessary.

(2) With a view to furnishing useful material for the theoretical developments, many measures have been made upon the mobility, the rate of recombination, and the diffusion at various temperatures and pressures. We will mention the measures of Phillips[43] (variation of k and a with the temperature), Kovorik,[44], Todd.[45]

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[24] These laws rest only on the Doppler-Fizeau principle, thermodynamical reasoning, and the pressure of radiation, principles which may be held as well proven if not as experimental facts.

[25] Rayleigh, *Phil. Mag.*, vol. 2, p. 539, 1900.

[26] Jeans, *l. c.*, vol. 10, p. 91, 1905; vol. 17, p. 229, 1909; vol. 17, p. 773, 1909; vol. 18, p. 209, 1909.

[27] Lorentz, *Revue générale des Sciences*, p. 14, 1909; La théorie du rayonnement (The theory of radiation), Rapports au Congrès de Bruxelles de 1911, publiés par Langevin and de Broglie.

[28] See the recent article by J. Perrin in the *Revue* for November 15th, 1912.

[29] These consequences have been resumed in a notable course of lectures given this year at the Collège de France by Langevin.

[30] Brillouin, *Comptes Rendus*, vol. 156, pp. 124, 301, 1913.

[31] With regard to all these questions which we cannot stop to more than sketch, see the lecture which we delivered before the Société de physique in December, 1911, upon the electron theory of metals, and also the book which we have several times cited on the Theory of Radiation.

[32] Weiss, *Journal de physique*, pp. 900, 905, 1911.

[33] Langevin, *Annales de chimie et de physique*, vol. 5, p. 70, 1905.

[34] Ritz, *Annalen der Physik*, vol. 25, p. 660, 1908.

[35] Pascal, *Ann. Ch. Phys.*, vol. 16, p. 531, 1909; vol. 19, p. 5, 1910.

[36] Mlle. Feytis, *Comptes Rendus*, vol. 152, p. 708, 1911.

[37] Sève, *Ann. Ch. Phys.*, vol. 27, p. 189, 1912.

[38] Weiss and Piccard, *Comptes Rendus*, vol. 155, p. 1234, 1912.

[39] Langevin, Rapport à la Conférence de Bruxelles, 1911.

[40] Sutherland, *Phil. Mag.*, vol. 18, p. 341, 1909.

[41] Wellisch, *Phil. Trans.*, vol. 209, p. 249, 1909.

[42] Reinganum, *Phys. Zeitschr.*, vol. 12, pp. 575 and 666, 1911.

[43] *Phillips, Proc. Roy. Soc.*, 1906, and vol. 83, p. 246, 1910.

[44] Kovorik, *Phys. Rev.*, vol. 30, p. 415, 1910; *Proc.*, vol. 86, p. 154, 1912.

[45] Todd, *Radium*, p. 113, 1911; p. 465, 1911.

Dempster,[46] (variation of K at high and low pressures), Sales[47] (variation of D with the pressure). These measures show that ionic agglomerations disintegrate faster at low pressures and high temperatures in the case of negative ions and tend for both positive and negative ions to revert to the primitive state. This is in accord with the measures made upon flames by Moreau,[48] Lusby,[49] H. A. Wilson, and others.[50] The negative ions in flames appear to differ little from corpuscles and are scarcely loaded in their accidental encounters with molecules. The positive ion has a size of the order of magnitude of a free atom-ion and often appears to be formed of an hydrogen atom, more rarely of a metallic atom in certain flames colored by salts.

(3) It is mostly with ionization at ordinary temperatures that the newer results have been obtained. The study of ionized gaseous mixtures was first undertaken by Blanc[51] and by Wellisch.[52] According to them an ion produced in a gas A and then transported into another gas B, assumes a mobility characteristic of the gas B. This agrees with the idea of temporary agglomerations constantly destroyed and built up again. Blanc carried out his experiment with ions formed in carbonic acid gas and then transported into air. Wellisch created his ions in CH_3I of CCl_4 and then transported them into hydrogen. According to him the ionization in hydrogen is enormously increased by traces of CH_3I, whereas the mobility changes only slightly. It looks as if the heavily ionized molecules of CH_3I transfer their charges to the hydrogen molecules. This is a remarkable property belonging to certain ions. The same experimenters, as well as Lathey,[53] Tyndall,[54] and others, have studied with precision the influence of traces of a foreign gas upon the mobility of ions. According to Blanc, a small amount of aqueous vapor diminishes the mobility of the negative ion and increases that of the positive ion in air and in carbonic acid gas (450 and 490 C. G. S. for air instead of 380 and 600). The same occurs with alcohol vapor. The molecules of water and alcohol without doubt remain longer associated with the charged nucleus than those of air, carbonic acid gas, or hydrogen. Just the opposite is the case with the molecules of CH_3I, CCl_4, etc. From this we see also that in certain gases the positive ions finally surpass the negative ions in mobility. This, for instance, happens with chlorine.

The most remarkable fact in this connection was noted by Franck.[55] Working upon argon he found normal mobilities (of the order of 1 centimeter in a 1 volt-centimeter field) for the positive ions, while the negative ions had mobilities of more than 200 centimeters and behaved as corpuscles free from corteges of molecules during the major part of their courses in the gas. This enormous mobility diminishes very rapidly under the least trace of oxygen; it is brought down to 1.7 centimeters by 1.5 per cent of oxygen. The tendency to associate with the oxygen molecules is therefore much greater than with the argon atom. Nitrogen shows a behavior analogous to argon.

(4) The study of the charge carried by the ions has led also to important results. The method used for measuring the charge e is based upon the condensation of water-vapor upon the ions (Townsend and J. J. Thomson) and has been further perfected by Millikan[56] and his pupils. By means of a microscope a single drop of oil or other material charged by the ionized gas is observed between the horizontal plates of a condenser. Its rates of rise or fall due to the combined electrical and gravitational fields are followed, and from these rates the charge e may be computed. Thus by observing the sudden changes in the rates the new charges can be noted as they are added to or taken away from the drop. It is found that these modifications of the charge of the drop always occur in whole multiples of the same elementary charge, e. The mean of the numbers found for e was 4.89×10^{-10} electrostatic units. This number accords with that deduced by Rutherford from his measures with the rays, although J. Perrin found somewhat smaller values from his study of emulsions and of the Brownian movement.

An important fact was noted by Townsend[57] and his students: Ions of double charge, $2e$, or multiples of this, were found in ionized gases. This was noted in the experiments made in 1899, by means of which Townsend, measuring the diffusion coefficient D by a method using a gaseous current and comparing it with the mobility k was able to determine the product Ne of the charge of the ion by the Avogadro's number (the number of atoms per atom-gramme). This was a static method and permitted the evaluation directly of the quotient k/D which equals the product Ne. This result was dependent upon the method of ionization used. At mean pressures and with the α rays from radium in air or the secondary rays due to X-rays produced upon polished brass in hydrogen or oxygen, slightly moist, ions of opposite sign were both found to give nearly the value 1.24×10^{10}. However, if the secondary rays are produced in air at a sheet of brass, oxidized or covered with vaseline, or in other gases (hydrogen, oxygen, carbonic acid) upon the same strip polished and covered with vaseline, the value of Ne is much greater for the positive ions. It may be found as high as 2.4×10^{10}. We conclude therefore first, that certain positive ions carry a charge $2e$; second, that such ions are produced by the more penetrating secondary rays which are not absorbed by the vaseline. The existence of the polyvalent ions has been confirmed by Franck and Westphal,[58] who returned to the older method, using a gaseous current and devised by Townsend, in which K and D are separately measured. With X-rays the proportion of polyvalent ions is about 1/10; with the α rays of polonium or the β rays of radium there seem to be no polyvalent ions. Millikan and Fletscher[59] do not agree with these conclusions, basing their objections upon the method of drops earlier described. But the earlier physicists maintain their interpretation, which also seems to be in good accord with the results from other methods (multiple charges of the α rays from radium, of the canal rays, the positive rays of vacuum tubes, according to J. J. Thomson, Gehrke, and Reichenheim and others).

However, the question must seem at present unsolved. Very recently, Langevin and Salles,[60] measuring the ratio K/D by a new direct method, have concluded against the existence of polyvalent ions in the ionization by X-rays. We must therefore still leave the question open.

(5) Finally, we must note the remarkable experiment by which C. T. K. Wilson[61] has enlightened us as to the mechanism of ionization. Continuing his celebrated experiments on the condensation of water vapor on ions, he succeeded in *seeing and photographing the trail of ions*, produced in a gas by an angle α or β particle from radium or a very narrow pencil of X-rays.

His admirable photographs themselves alone can give an idea of all of which we can learn from them. Upon them we see the α and β particles following their rectilinear trajectories; we learn that the X-rays do not ionize directly but by the secondary rays which they tear from the molecules encountered in the gas, etc. We find also a direct verification of the hypothesis advanced by Langevin and put to experimental test by Moulin[62] in order to explain the "initial recombination" discovered by Bragg. According to the latter, the saturation current of a gas ionized by α rays is much more difficult to obtained than when X-rays are used. This is due, not to an "initial recombination" between the positive atom ions and electrons just liberated, but to a localization of the ions along the path of the α particles; a saturation current is indeed much easier to obtain when the field is perpendicular to the radiation than when parallel.

VI. PHOTOELECTRIC EFFECT. (HERTZ AND LENARD EFFECTS.)

Light, and especially ultra-violet light, discharges negatively electrified bodies with the production of rays of the same nature as cathode rays. Under certain circumstances it can directly ionize gases. The first of these phenomena was discovered by Hertz and Hallwachs in 1887. The second was announced first by Lenard in 1900. Perhaps on no subject is the literature of the day greater and more contradictory, so we will note only a few of the recent results upon which the bulk of the work has been done.

(1) With regard to the Hertz effect, the researches from the start showed a great complexity of the phenomenon of photoelectric fatigue; that is, the progressive diminution of the effect observed upon fresh metallic surfaces. According to an important research by Hallwachs,[63] ozone plays an important part in the phenomenon. However, other elements enter such as oxidation, the humidity, the mode of polish of the surface, etc. We are not even sure that the fatigue is absent in a vacuum. Eugene Bloch[64] insists that we should work with an exciting radiation of definite wave-length since the fatigue varies from one wave-length to another. He also showed that in certain instances there is an acceleration of the effect which has been refound by various workers.

A great many experiments have been made in a vacuum. Some were undertaken to study the Hertz effect at the rear surface of a strip traversed by the light, an effect perhaps greater there than at the front surface (Stohlmann, Kleemann, and others). Other experimenters have shown a selective effect in the case of certain metals; for instance, with the alkaline metals, according to Pohl and Pringscheim,[65] there are maxima of exciting power at wave-length 0.300 μ for sodium, at 0.436 μ for potassium, and at 0.390 μ for a liquid alloy of potassium and sodium. The general exciting power increased regularly toward the smaller wave-lengths. Several workers have also endeavored to extend the photoelectric sensitiveness of photoelectric cells into the infra-red (Elster and Geitel) or to utilize them for photophony (Bloch).

However, the greatest effort has been spent in order to find out in vacuum the variation of the initial velocities of the photoelectric electrons with the wave-length. This problem has a great theoretical interest, and the simple laws stated by Lenard since 1900 for the ensemble of radiation emitted should be studied separately for each wave-length of the exciting radiation. According to Lenard, the total number of electrons emitted is proportional to the intensity of the incident light, but their velocity is independent of it, as well as of the wave-length for any given metal. This odd result does not at all agree with the quanta hypothesis which, according to Einstein, leads to a linear variation of the initial energy $mv^2/2$ with the frequency. We may further in our measures replace the initial velocity by the maximum positive potential V which the metal can take under the influence of the rays (that is, the potential of the stoppage of the electrons). The first measures made upon this matter by Ladenburg[66] showed an increase of the initial velocity with the exciting frequency. Taken up by Ladenburg and Markav,[67] Hull,[68] Hughes,[69] Richardson,[70] and others, the experiments have confirmed, although not without dispute and difficulty, the qualitative result of Ladenburg and apparently the theoretical law of variation due to Einstein. Certain writers contest this last deduction and claim a parabolic in place of a linear law of variation.[71] Our own unpublished experiments completed upon this question lead us to reserve our decision, because of the smallness of the ranges of wave-lengths studied by all these experimenters. It will be necessary to take up with quartz apparatus this question, working with the alkaline metals from the visible spectrum way up to the extreme ultra-violet. This is the only procedure which will allow a real experimental test of the theory of quanta. We will close with the results obtained by Millikan[72] and his pupils, who have found in certain cases abnormally high initial velocities. It looks as if there might be some experimental error due to the mode of production of the discharge by the ultra-violet light and the influence of the electric waves from the source upon the measuring apparatus.

(2) The discovery of the ionization of gases by ultra-violet light was made by Lenard in 1900. As the effect was produced across several centimeters of air and made very great positive and small negative ions, it was natural to interpret the phenomenon, as did J. J. Thomson, as an Hertz effect upon the solid or liquid particles present in the gas. The researches of Langevin and those of Eugene Bloch[73] have shown, indeed, that the greater part of the Lenard effect is certainly due to this cause.

The Lenard effect upon the gas itself nevertheless does exist. Refound by J. J. Thomson[74] and then more decisively by Palmer,[75] it has already been considerably studied and shows very different characteristics than those at first attributed to it by Lenard. It seems to be produced exclusively by the Schumann or extreme ultra-violet rays of wave-length less than 0.180 μ. These rays

[46] Dempster, *Phys. Rev.*, vol. 34, p. 53, 1912.
[47] Sales, *Radium*, p. 59, 1911.
[48] Moreau, *Comptes Rendus*, vol. 148, p. 342, 1909; *Radium*, p. 70, 1910.
[49] Lusby, *Proc. Cambr.*, vol. 16, p. 26, 1911; *Phill Mag.*, vol. 22, p. 775, 1911.
[50] H. A. Wilson, *Phil. Mag.*, vol. 21, p. 711, 1911.
[51] Blanc, *Journal de physique*, vol. 7, p. 838, 1908.
[52] Wellisch, *Radium*, p. 241, 1909, and l. c.
[53] Lathey, *Proc. Roy. Soc.*, vol. 84, p. 173, 1910.
[54] Tyndall, *Nature*, vol. 84, p. 530, 1910.
[55] Franck, *Verh. Deutsch. Phys. Gesellsch.*, vol. 12, p. 291, 1910.
[56] Millikan, *Radium*, p. 345, 1910; *Phys. Rev.*, vol. 32, p. 349, 1911.
[57] Townsend, *Proc. Roy. Soc.*, vol. 80, p. 207, 1908; vol. 81, p. 464, 1909; vol. 85, p. 25, 1911; Haselfoot, *Proc. Roy. Soc.*, vol. 82, p. 18, 1909.
[58] Franck and Westphal, *Verh. der Deutsch. Phys. Ges.*, vol. 11, pp. 146 and 276, 1909.
[59] Millikan and Fletscher, *Phys. Rev.*, vol. 32, p. 239, 1911, and *Phil. Mag.*, vol. 21, p. 753, 1911. See also Townsend, *Phil. Mag.*, vol. 22, p. 204, 1911; Franck and Westphal, *Phil. Mag.*, vol. 22, p. 547, 1911.
[60] Langevin and Salles, Société de chimie physique, February, 1913.
[61] Wilson, *Proc. Roy. Soc.*, vol. 85, p. 285, 1911; *Radium*, January, 1913.
[62] Moulin, *Radium*, p. 350, 1910.
[63] Hallwachs, *Annalen der Physik*, vol. 23, p. 459, 1907.
[64] Bloch, *Radium*, vol. 23, p. 125, 1910.
[65] Pohl and Pringscheim, *Verh. der Deutsch. Phys. Ges.*, vol. 12, pp. 215, 349, 1910.
[66] Ladenburg, *Phys. Zeitschr.*, vol. 8, p. 590, 1907.
[67] Ladenburg and Markav, *Phys. Zeitschr.*, vol. 9, p. 821, 1908.
[68] Hull, *Phys. Zeitschr.*, vol. 10, p. 537.
[69] Hughes, *Phil. Mag.*, vol. 21, p. 393, 1911; *Proc. Cambr.*, vol. 16, p. 167, 1911.
[70] Richardson, *Phil. Mag.*, vol. 24, pp. 570, 575, 1912.
[71] Kuntz, Cornelius, *Phys. Review*, 1910 and 1913.
[72] Millikan and Wright, *Phys. Review*, January and February, 1911.
[73] Bloch, *Radium*, p. 240, 1908.
[74] Thomson, *Proc. Cambr.*, vol. 14, p. 417, 1907.
[75] Palmer, *Nature*, vol. 77, p. 582, 1908; *Phys. Rev.*, p. 1, 1911.

will not pass through air, although they will through fluorite and partly through quartz. It produces small ions of both signs, neutral centers, large ions, and ozone. It is extremely sensitive to minute traces of impurities in the gas, traces which cannot be detected by other means. It can be distinguished from the Hertz effect and become very much greater. All these conclusions are drawn from the researches of Hughes,[76], Cannegieter,[77] Lenard and Ramsauer,[78], and Leon and Eugene Bloch.[79] The latter have shown also that the radiation transmitted by quartz and coming from a mercury arc ionizes the air feebly in the neighborhood of the arc and seems consequently to emit a small amount of Schumann rays. In place of the usual source of Schumann rays, a hydrogen tube furnished with quartz windows, Lenard and Ramsauer used a very powerful spark between electrodes of aluminium. Then the ionization takes place even through air and quartz and the experimenters attribute it to rays of wave-length less than 0.1 $\mu\mu$, the smallest ultra-violet rays known, and which were discovered by Lymann. As no measure of these wave-lengths was made, it seems as probable that the effect is due to ordinary Schumann rays which have been partially transmitted by media generally opaque to them because of the great original intensity of the light. This question remains to be studied as well as the Lenard effect in general, the knowledge of which is yet very limited despite the great number of interesting problems connected with it.

The Problem of the High Building

By Prof. Charles Peck Warren, Assistant Professor of Architecture, Columbia University

THE question is frequently asked, Will America ever develop a style of architecture? Probably the nearest we have come to it is in the erection of the skyscraper—the most striking and characteristic feature of American architecture—although this is but a step in the development.

The demand for the skyscraper is an outcome of conditions peculiar to New York, although Chicago claims the honor of having erected the first steel skeleton building. Manhattan Island is so narrow and its trade center is so near one end that the rapid increase in trade since 1870 has necessarily been confined in a limited area, and in consequence the land there has advanced rapidly in value.

The first direct result of the menace in the height of buildings was the invention of passenger elevators for commercial buildings, for it was soon discovered that tenants would not mount stairs above four, or, at the most, five stories. Elevators were employed for the first time in the Fifth Avenue Hotel in 1856, and later on, in 1868, in the old Equitable Building, destroyed by fire in 1911. The gradual development and improvement in high speed made vertical travel easy and comfortable, and the erection of six, then seven, eight, and finally nine-story buildings became possible. So that the problem of making downtown real estate investments profitable was thus temporarily solved.

As years went on, however, even nine-story buildings in which the cheapest offices rented for $2 per square foot of floor space ceased to yield sufficient revenue, owing to the constant rise in real estate values, so that the height of buildings had to be raised to ten and twelve stories. It was soon discovered that these tall buildings, constructed as they were of combustible materials in the floors, stairs, and elevator wells, could not be controlled in case of fire, so the Building Department in 1882 passed a law requiring buildings exceeding eighty-five feet in height to be fireproof.

This gave a great impetus to steel construction, and buildings such as the Mills, Morse, and Post were erected, in which, for the first time, the floor beams and interior columns were made of iron or steel. The further development of steel construction made it possible to erect a safe and economical building rising to a greater height.

A new difficulty here presented itself. Under the old system of construction the outer walls became so thick at the base, when the building was carried up twelve or fifteen stories, as to cause a loss of income to the owner, as, on a narrow lot, little more than an entrance hallway would be left. It became necessary to make the walls thinner, and this resulted in the construction of curtain walls and skeleton frames.

The masonry walls are not needed for strength; they are divided into sections and supported by the steel frame. A twelve-story building, for instance, would require 36-inch bearing walls on the first floor, but only 20-inch skeleton walls, saving nearly three feet in the width of the building, or over 10 per cent on a lot 25 feet wide. The walls of the Woolworth Building are 4 feet 4 inches thick at the base. Under the old method they would have been 10 feet 4 inches.

What is the limit to the height of buildings? The answer is the height at which the building ceases to yield a sufficient income on the investment. There is no doubt of the possibility of erecting a building 1,000 feet high—say, seventy-five stories—but would it pay?

An examination of the records of the Building Bureau shows that the increase in the height of buildings is not represented by a steady upward line of growth, but by an irregular line in which the upward tendency is interrupted at intervals by lines of depression.

Starting with the year 1890, which marked the beginning of the development of the steel skyscraper, the height rapidly increased to eighteen stories, reached by the Mutual Life Insurance Building in 1892. Then followed a reduction lasting two or three years, and then an upward movement culminating in 1896 in the twenty-four-story Park Row Building. The following decade witnessed a slight repression until about 1900, and then a rapid turn upward to forty-two stories attained by the Singer Building in 1906. Another ebb followed, and then a rise which was topped in 1912 by the Woolworth Building with its fifty-five stories.

A congestion of skyscrapers in any community is objectionable for several reasons; it is dangerous to life, menace to health, and it impedes traffic. It is quite true that the modern building can be made fireproof, but when filled with inflammable material, it becomes, in effect, merely a stove or a furnace in case of fire. A large percentage of so-called loft buildings are used for manufacturing purposes, for which they were not designed. Under the present building code it is still possible for owners to pervert the uses of their buildings. When the new code is adopted the provision requiring a certificate of occupancy to be filed with the plans will operate to prevent this condition.

In regard to the second cause, the dark rooms in which thousands must work, cut off from light and air by the adjoining tall buildings unquestionably have a damaging effect upon the health of the occupants. This, however, might not have any effect in limiting the height of buildings, but the fact that these darkened lower floors yield a smaller revenue will have its effect.

Concerning the third cause, it does not need any elaborate explanation to show that tall buildings bring about a thoroughly undesirable congestion of population. Start to walk up Fifth Avenue from Fourteenth Street any day at the noon hour. It is almost impossible, because of the tremendous outpouring of the occupants of the adjoining loft buildings. The result is the neighborhood is shunned, and shops become undesirable, rent falls and the buildings fail to return a proper percentage of profit on the land. When this happens either the building must be torn down and be replaced by a more remunerative one or land values will decrease.

The future uncertainty of land values in New York city will also have a tendency to discourage the erection of high buildings. Hitherto the tendency of values has been almost uniformly upward, but in the last few years there has been in some quarters, notably in the Broadway section above City Hall up and in lower Fifth Avenue, a tendency in the opposite direction. Who can foretell with any certainty the effect of the future subways and tunnels upon land values? Suppose the vast outlying area should be developed for manufacturing purposes, of what use would be the loft building?

A skyscraper is not necessarily a money-making investment. The majority return rents less than many other forms of investment, and some of them actually lose money. It is a sad commentary on the life of a skyscraper that the first, the Tower Building, 52 Broadway, erected in 1888, was torn down in 1913. Why? Because it did not pay, and on its site is being erected a low arcade stone structure equivalent in height to the average four-story building.—*New York Times.*

New Instruments of Precision

THE work of Dr. W. Rosenhain, F.R.S., of the National Physical Laboratory, is very well known to engineers, particularly through his clear and comprehensive reports to the Alloys Research Committee of the Institution of Mechanical Engineers. Besides being a scientist of international repute Dr. Rosenhain is an inventor, and three of his latest instruments are described in his recent Institute of Metals paper on "Some Appliances for Metallographic Research." All three were worked out in the metallurgy department of the National Physical Laboratory in order to increase the accuracy and convenience of research work of the highest kind. The simplest is a little optical device for the accurate leveling of metal specimens for the microscope. A beam of light, reflected from the polished surface of the metal, is used as an index whereby the surface can be quickly and easily set truly horizontal. The other two instruments deal with problems which arise in the preparation of accurate cooling and heating curves. One of these problems is that of heating and cooling specimens of metal at any desired rate which shall remain constant over a wide range of temperatures. This is attained by the use of vertical tube furnaces so arranged as to be hot at one end and cold at the other, with a uniform gradation of temperature between the two ends. The specimen is raised or lowered in this tube, and is heated or cooled accordingly, the rate being easily varied by altering the rate of raising or lowering. A "blank" heating curve reproduced in the paper shows a maximum variation for 2 deg. Cent. ranging only between 12 seconds and 20 seconds over a temperature range of 700 deg. Cent.

The third appliance described, says the *London Daily Telegraph*, is a "plotting chronograph," by means of which the "inverse rate" curves, so freely used in metallographic research, are plotted automatically to a very large scale, the observer merely tapping a key as the various temperature intervals are passed. The instrument, which thus not only acts as a chronograph, but at once plots the readings in the shape of a curve, is somewhat complex. Its accurate and satisfactory working, however, is testified by the curves with which the paper is illustrated.

[76] Hughes, *Proc. Cambr.*, vol. 15, p. 483, 1910.

[77] Cannegieter, *Proc. Amst.*, p. 1,114, 1911.

[78] Lenard and Ramsauer, Sitzungsber. Heidelberg, 1910-1911.

[79] Leon and Eugene Bloch, *Comptes Rendus*, vol. 155, pp. 903, 1,076, 1912.

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